RESPONSE OF *DIEFFENBACHIA SPP* TO NITROGEN SOURCES, CALCIUM AND SOLUBLE SALTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Commercially grown Dieffenbachia is usually subjected to higher levels of fertilization and light than are recommended in the literature. Growers feel they are getting faster growth and better quality plants, but are experiencing problems that could be due to their cultural practices.

Several foliage disorders have been observed on Dieffenbachia which have not been explained by the presence of pathogenic organisms. Of particular interest are an orange-red necrotic spot on Dieffenbachia amoena Bull. cv. 'Tropic White' and a tip burn on the lower leaves of Dieffenbachia maculata (Lodd.) G. Don cv. 'Perfection Compacta'.

Orange-red spots were reported on the Tropic White cultivar grown under 50% shade and higher than recommended fertility levels when subjected to water stress. Urea of unknown purity was used as a nitrogen source. Biuret as a contaminant in the urea was suspected of having some relationship to the incidence of the spots as it occurred after switching to this nitrogen source and disappeared when this source of fertilizer was dropped. High light and elevated levels of soluble salts would increase plant stress when water was withheld which could, in turn, increase the incidence of spotting.

Leaf tip burn has been most evident on Dieffenbachia maculata 'Perfection Compacta'. The Plant Pathology Disease Clinc has been

unsuccessful in finding any primary pathogen consistently involved in the leaf tip burn. Soluble salts are considered a possible cause due to the high levels of fertilization. Calcium is suspected of being involved as the incidence of the tip burn in commercial production seems to vary with calcium fertilization. Symptoms appear to be more severe both on plants deficient in calcium and in plants fed high levels of calcium.

Through the course of this study, questions were raised about the effect of nitrogen sources on dieffenbachia. While nitrate sources are most commonly recommended for pot culture, ammonium and urea are gaining greater acceptance due to their lower cost. Dieffenbachia for export are grown in soilless media lacking beneficial organisms such as nitrifying bacteria. In such media, dieffenbachia must absorb and assimilate nitrogen in the form it is applied.

The primary purpose of this study was to characterize several foliage disorders affecting commercial dieffenbachia production and try to pinpoint the factor or factors causing the problems. Experiments were designed to examine probable causes of the orange-red spotting on Dieffenbachia amoena 'Tropic White' and the leaf tip burning on Dieffenbachia maculata 'Perfection Compacta', the effects of nitrogen sources on Dieffenbachia and the proper leaf to sample in Dieffenbachia tissue analysis.

LITERATURE REVIEW

Dieffenbachia Culture

Dieffenbachia are grown in Florida under 3000-4000 ft-c of light, usually under 63-73% shading. Recommendations for Hawaii are for 73% shade, although several growers believe that by using 50% shade, they can increase production and quality. Conover and Poole (16), though, found that Dieffenbachia amoena, when grown for 6 months under 60% and 80% shade, did not differ in height, leaf size or number of leaves. Therefore, they recommended that dieffenbachia be grown under 80% shade to produce plants better acclimated to indoor conditions.

Fertilizer recommendations for dieffenbachia vary, depending on the light level, media, irrigation method and cultivar. Most recommendations call for N:P:K in either a 1:1:1 or a 3:1:2 ratio (16,17,18,29,67). Recent data indicates that a 1:1:1 ratio may be unnecessarily high in P and K (19). Good growth was obtained with ratios of 3:1:2 and 10:1:6.

Fertilizer may be applied either as liquid feed via an irrigation system or dry in a slow release form. In two experiments comparing Osmocote and weekly applications of liquid feed, Osmocote produced significantly taller plants with larger leaves and better root systems than liquid feed (17,18). Soluble salt levels were significantly higher

under Osmocote nutrition, but not restrictive to the plants. No comparisons have been made, though, between constant liquid feed and slow release fertilizers.

The rate of nutrient application varies with the fertilization method. Waters and Llewellyn (67) found best growth in Dieffenbachia amoena with 1800 kgN/ha/yr. Conover and Poole (16) recommended 1100-1600 kgN/ha/yr as Osmocote, but found no significant differences between 560 and 2240 kgN/ha/yr in their tests comparing Osmocote with liquid feed (17,18). Henley and Poole (29) found best growth under constant liquid feed at levels between 150 and 450 kgN/ha.

Pathogens of Dieffenbachia

Dieffenbachia is host to many plant pathogens that may weaken, kill or render it unsalable. In nutritional studies, plant pathogens must be closely watched as disease symptoms can be confused with nutritional disorders. Further, a plant under nutritional stress may be more susceptible to attack by pathogens.

There are a number of fungi which infect dieffenbachia stems and foliage. Serious leaf spot problems can be caused by Phytopthora, Leptosphaeria and Collectotrichum (10,44). Stem rots can be caused by Fusarium as well as the common damping-off fungi under favorable conditions (11).

Bacteria are responsible for serious losses in dieffenbachia. Stem

and leaf rots caused by Erwinia appear as water-soaked, sunken lesions on the stem and irregular soft spots on the leaves (49,51). Xanthomonas, which produces a serious dieback in anthurium, causes much less serious leaf spots in dieffenbachia. The 1-10 mm spots are dull watery-green, surrounded by a bright, yellow-orange area (48). A new dieffenbachia cane rot complex, which requires the presence of both the bacteria Erwinia and the fungus Acremonium, has been observed on D. 'Exotica' cuttings in Hawaii (1). This disease produces irregular cavities on the stem, frequently with red margins. Plants become unthrifty and the lower leaves turn yellow.

Dasheen mosaic virus is a serious problem in dieffenbachia. Many cultivars do not show symptoms under normal conditions, but are reduced in vigor. Propagation of infected but symptomless plants perpetuates the virus in all further cuttings. Stressed plants may show symptoms varying form a dulling of the color in the 'Perfection' and 'Marianne' types, to color breaks and ring spots in the amoena and 'Rudolph Roehrs' types respectively (9,12).

Tissue Analysis

Plant tissue analysis can indicate the relative concentration of nutrients in the plant. The goal of tissue analysis should be to define a range of elemental concentrations at which best growth occurs. The lower level of the range defines the critical concentration for an element below which some visible growth character is reduced. Ranges

are given because the critical concentration of one element varies with the concentrations of other elements in the plant (3,61,62).

Sampling for tissue analysis is usually restricted to leaves, although tissues such as roots and bark have been used with varying degrees of success (61). Leaves are where most chemical reactions in the plant occur, so they have the potential to reflect the current nutritional status of the plant. Leaves are also the most practical for testing as they can usually be removed without significantly affecting the plant being sampled.

Leaf to sample

There are many factors affecting the nutrient balance in the leaf, so great care must be taken in choosing the proper leaf for sampling. Probably the most critical factor is the age of the leaf. Young leaves in active growth and expansion vary widely in their analyses. Similarly, as senescence approaches, there is a wide variablility in nutrient levels as some elements are accumulated and others removed to parts of the plant under more active growth (61). Between these two periods, specific leaf ages have been found to be significantly better at predicting the nutrients available to the plant (40,41,52,53,63,70). The most recently mature, fully expanded leaves are usually recommended for plant tissue analysis (21). Other factors such as the position of the leaf in the vegetaion canopy, its direction of exposure, and microclimate factors can have significant effects on the nutrient balance in certain plants (8,41).

Portion of leaf to sample

Tissue analysis results differ depending on the portion of the leaf being sampled. Significant differences can usually be found between leaf and petiole analyses. More consistant measurements can be obtained by discarding the petiole in tissue analysis of grapes and currants (61). Nelson and Boodley (52) found the basal portion of the carnation leaf to be best for K and Ca analyses, and the terminal for boron.

Sampling for specific elements

Tissue age can greatly affect the results of analysis for specific elements. With some exceptions, N, P, K, Cu, and Zn seem to decrease in concentration with age, while Ca, Mg, Mn, Fe and B seem to increase (59,61,63,70,71). This is related to the mobility of the elements and their redistribution or non-redistribution within the plant. Mobile elements such as N and K will be translocated to new growth from older tissues in the event of a deficiency. Immobile elements such as calcium may be tied up in the cellular structure and unable to be removed from older tissues (61).

The selection of a single tissue sample to reflect the elemental status of the whole plant requires a compromise in the choice among the best tissues to analyse for each individual element (33,52). Conover and Poole (19) use the most recently mature, fully expanded leaves for dieffenbachia tissue analysis. This is the recommended procedure for plant materials in which the optimum tissue has not been determined experimentally (21). The elemental composition of 'good quality' Dieffenbachia maculata 'Exotica' was N 2.5-3.5%, P 0.20-0.35%, K

3.0-3.5%, Ca 1.0-1.5%, Mg 0.30-0.80% (28,56).

Salinity

Problems due to high levels of soluble salts may occur any time plants are grown under high levels of nutrition or with saline soil or water sources. Foliage plants, though, are not considered highly sensitive to soluble salts (15). Joiner, Conover and Poole (36), consider dieffenbachia to be of average salt tolerance.

Damage to plants due to soluble salts usually begins with root injury due to osmotic shock and commonly manifests itself above ground as wilting and necrosis of leaf margins and tips. Soluble salts may compete with minor elements for uptake, resulting in deficiencies (15). In less severe cases, soluble salt injury may only be observed as a reduction in growth, with no other noticeable symptoms.

Conover and NeSmith (15) stated that the general range of soluble salt levels for foliage plants varied from less than 400 ppm, considered too low for adequate nutrition, to greater than 1450 ppm, at which injury may occur in sensitive plants. This range varies with the medium and soluble salts present.

In contrast, Frear (26) studied the effect of soluble salts on Dracaena deremensis in quartz sand nutrient culture. No significant differences were found between the controls at 2.5 mmhos/cm and the highest level at 10 mmhos/cm. This was surmised to be too low to show

significant differences as Dracaena is fairly salt tolerant (6).

Under field conditions, Berstein, Francois and Clark (6) observed the tolerances of ornamental shrubs and ground covers to varying levels of soluble salts in artificially salinized plots. Tolerant species were little affected by salt levels up to 8 mmhos/cm, while sensitive species were damaged or killed at 4 mmhos/cm. Monk and Wiebe (50) found tolerant trees and shrubs surviving up to 8 mmhos/cm in the soil. Richards, at the California Salinity Laboratory, considered 3 mmhos/cm the highest level of soil salinity tolerated by field crops (34).

Monk and Wiebe (50) studied the salt tolerance of herbaceous ornamentals under solution culture. Petunias and portulaca were not visibly affected by the highest salt level of 8 mmhos/cm. In lilies, leaf tip burn was observed at as low as 1.5 mmhos/cm with more necrosis and bud blasting occurring at 4 mmhos/cm (39). Hughes and Hanan (34) found yields significantly reduced in greenhouse roses at 1.8 mmhos/cm.

Calcium

Calcium has been shown to be involved in tip dieback and leaf spot problems in several crops (20,31,32,42,45,46). Dieffenbachia has leaf tip dieback problems which could be related to its calcium nutrition.

The majority of the calcium required by higher plants is used as a constituent of the cell wall. Calcium is also necessary for the activation of many enzyme systems and in the regulation of the cell

membrane permeability to specific ions. Calcium has been shown to be necessary for the preferential absorption of potassium in the presence of high concentrations of sodium, serving as a barrier to sodium in saline environments (57).

In well mangaged soils, calcium is the dominant ion in the exchange complex. Calcium uptake occurs preferentially at the root tips and at sites of branch root formation where the casparian strip is incomplete or disrupted. Since the casparian strip blocks calcium uptake, it is essential that roots undergo active growth at all times and that calcium be very well distributed through the soil. Calcium is taken up passively, by diffusion or displacement exchange. Transport of calcium occurs primarily in the xylem, although isolated cases of phloem transport have been observed (2). Calcium moves by active transport-exchange with negatively charged molecules such as lignins and pectins, so lagging behind mass flow (2).

Calcium uptake can be affected by many factors, both chemical and environmental. Potassium, magnesium and ammonium in the soil solution compete with calcium for uptake while nitrate and phosphate can stimulate calcium uptake (2,66). Lange et al. (43) showed that a lack of soil aeration in beans caused a 49% decrease in calcium uptake. Scaife and Clarkson (60) explained that brief periods of anaerobic conditions due to flooding or compaction can lead to a temporary reduction in the undifferentiated regions of the roots where calcium is absorbed and so to a calcium deficiency.

Periods of high relative humidity can cause a calcium deficiency

when the xylem stream slows and not enough calcium can be translocated to growing tissues (45,46). This is common in leafy vegetables where the inner head leaves have little transpiration. Little calcium is moved into the tissues, resulting in a calcium deficiency (20,42,46).

Since calcium is immobile, deficiency symptoms first appear on the youngest tissues: terminal buds, young leaves and root tips. The roots are usually the first tissues affected, with the young tips dying back, and subsequent new roots becoming necrotic also (27). In the upper portion of the plant, calcium deficiences usually show up as tip necrosis and deformation of the youngest leaves. Tip burn can also be observed in rapidly expanding leaves.

In the family Araceae, the only substantiated calcium deficiency was reported by Higaki, Rasmussen and Carpenter (31,32) in Anthurium andraeanum. They observed a color breakdown of the lobes of the spathe, occurring in plants grown in cinder medium fertilized with Osmocote. Electron microprobe x-ray analysis, along with tissue analysis, indicated uniformly low calcium in the affected tissues. Anatomical studies showed cell separation in the tissues, possibly due to the lack of calcium in the middle lamella.

Dickey and Joiner (22) used sand culture to establish calcium deficiency symptoms in Philodendron oxycardium and Scindapsis aureus. In their studies, calcium deficiency manifested itself first as small, yellow spots on the vine's basal leaves, progressing up the vine. The spots became necrotic and the leaves sometimes became thickened and leathery with raised, corky areas before abscising.

Calcium Oxalate

Calcium oxalate crystals occur in many plant species and in many types of organs and tissues. Most members of the family Araceae contain deposits of calcium oxalate as crystals within their cells. The function of these crystals is unknown, but many hypotheses have been proposed: as a calcium storage mechanism, for structural support, as a protective device against foraging animals, and as a mechanism for maintaining ionic balance within the plant (24). Zindler-Frank (73) found that the amounts of calcium and oxalate in the plant tissues varied with the amount of calcium applied. There was no evidence that calcium oxalate, once formed, could be redissolved if needed for deficient tissues.

A portion of the calcium available to dieffenbachia plants is tied up as calcium oxalate. This is reflected in tissue analyses which usually range from 1-3% calcium. In a dieffenbachia breeding study, progeny from several crosses were analysed for their calcium oxalate content. Significant differences were found under the same nutritional regime with no relationship found between the amount of variegation in the leaves and the calcium oxalate level of the tissues (72).

Nitrogen

Plants can take up nitrogen as ammonium, urea or nitrate (23). Each form is then processed by specific metabolic pathways. Ammonium is in the form needed for assimilation into proteins and amino acids when taken up by the plant. Plants cannot store ammonium to any degree, so it must be immediately synthesized into organic compounds. Urea may be hydrolysed to ammonia in the presence of urease, an enzyme found in most plants (58). Nitrate is taken up by the plant and can be stored, but must undergo reduction to ammonium in order to be assimilated into organic compounds (23).

Most plants studied have shown better growth with nitrate fertilization in the absence of nitrifying bacteria. Maynard and Barker (47) observed best growth in corn, bean, pea and cucumber with nitrate fertilization. Ammonium toxicity was observed when the pH was allowed to drop due to ammonium fertilization. Bennett et al. (4) showed best corn growth with nitrate ferilization. Ammonium fertilization resulted in poorly developed root systems and the death of some plants.

However, some plants have been shown to grow better with an ammonium nitrogen source when nitrifying bacteria have been eliminated. Ammonium has been shown to produce better growth in rice, azalea and epilobium (7). Colgrove and Roberts (14) found that ammonium gave better growth and was required in smaller amounts than nitrate for azalea. The pH of the azalea tissues under ammonium ferilization was lower than under nitrate fertilizaion. As improved growth was observed under nitrate

fertilization when the pH of the solution was lowered, they concluded that the beneficial effects of ammonium were primarily due to its ability to lower the pH of the tissues.

Several hypotheses have been proposed for the apparent ammonium toxicity and better growth with nitrate fertilizaion under sterile media conditions. Maynard and Barker (47) associated the ammonium toxicity in their experiments with the pH drop due to ammonium fertilization. Bennett et al. (4) hypothesized that the ammonium toxicity was caused in part by the loss of the energy released in the reduction of nitrate to ammonium. In periods of low photosynthesis, ammonium assimilation can cause a depletion of carbohydrate and an accumulation of organic acids (23). Vines and Wedding (65) found that ammonium inhibited respiration in barley and beet root tissues, and in spinach leaf tissues, probably by affecting the electron transport system.

Biuret

Biuret, a contaminant in commercial sources of urea, is formed by the heating of urea during the pelletization process (13). Injury to plants attributed to biuret toxicity was noted early in citrus, pineapple and avocado where foliar sprays of urea were common. Typical toxiciy symptoms due to foliar applications are an irreversible yellowing of the leaves starting at the tip and progressing across the leaf. The affected tissues turn necrotic after a period of time.

Biuret is readily taken up in urea sprays to the foliage, but it has also been shown to be absorbed by the roots of bush beans and translocated through the xylem stream to the leaves (13). Once accumulated in the leaf, biuret is not translocated and is broken down slowly, if at all. It has been found in leaves of some species from 8 months to 4 years after application (7,35).

Although little is known of the mode of action of biuret, it has been shown to cause a sharp drop in the total leaf protein (35,68). While there is no evidence of biuret breaking down protein, it has been shown to inhibit the incorporation of certain amino acids into leaf proteins.

Webster et al. (68) reported that urea applications seemed to increase the toxicity of biuret, suggesting that urea affects either the absorption or metabolism of biuret. Clark and Wallace (13), though, showed no significant differences in the effects of biuret with urea applications.

Biuret has been shown to affect plants at widely ranging rates. Barley growth was inhibited in sand culture by 15-20 ppm biuret (7). Urea sprays containing 2.5% biuret inhibited wheat germination and produced chlorotic tips in citrus when sprayed on the foliage (7,35). Commercial urea sources once contained up to 10% biuret as a contaminant, but now contain less than 0.5%, approximately 1 ppm biuret when 200 ppm nitrogen is applied. This is considered by manufacturers to be low enough to cause no problems with biuret toxicity.

MATERIALS AND METHODS

General Setup

The four nutrition experiments were conducted using the sand culture methods of Hewitt (30). The plants were grown in washed and sterilized quartz sand. Nutrient solutions were applied to the plants by gravity fed systems with each irrigation. The plants were irrigated with nutrient solutions three times each week and then leached on weekends to prevent soluble salt buildup.

The experiments were conducted at the Mid Pac Research Facility on the University of Hawaii Manoa Campus under polypropylene shadecloth of 54% (6000 ft-c) and 73% (3400 ft-c). Temperatures in this area range from 18-29°C in the winter and 21-32°C in the summer (26).

The standard fertilizer solution for the experiments consisted of 200 ppm each of nitrogen and potassium, 65 ppm each of phosphorus and sulfur, 196 ppm of calcium and 50 ppm of magnesium. The nutrient sources were fertilizer grade calcium nitrate, potassium nitrate and magnesium sulfate. Reagent grade potassium acid phosphate was also used. The pH was adjusted to approximately 5.9 with 0.1 molar sodium hydroxide. Commercial slow-release micronutrient preparations were incorporated into the medium at recommended rates (Appendix Table 1).

A nutrient ratio of 3:1:3 was used as a compromise between the 3:1:2

ratio now recommended for foliage plants (19) and general recommendations for equal amounts of nitrogen and potassium. The higher level of potassium was used as growers report dieffenbachia to be heavy feeders of potassium, reflected in their tissue analysis (69).

Fertilizer solutions were held in 20 liter plastic containers attached to black polyethylene pipe with tygon tubing. A pinchcock on the tygon tubing was removed to allow each irrigation. Feeder tubes 61 cm long were attached to the polyethylene pipe and placed in each pot. The solution containers, painted to prevent algal growth, were placed 48 cm above the greenhouse bench to allow sufficient head for irrigation.

Tip cuttings of Dieffenbachia spp. obtained from local nurserymen and stock plants at the Mid Pac saranhouse were rooted in sterilized quartz sand in plastic pots under 500-1000 ft-c of light. Once sufficiently rooted, the plants were graded by size and grouped into replicates. All experiments were set up as Randomized Complete Block designs with the exception of Experiment I, which was designed as a Split-Plot. Five single plant replications were used for each treatment.

Unless otherwise specified, the first fully expanded leaves were used for tissue analysis. After rinsing in deionized water, the leaves were dried at 60°C, then ground in a Wiley Mill. Analysis was performed with the University of Hawaii X-ray Quantometer, model #73000.

Data were collected on many morphological characters to help determine the effect of the treatments on growth parameters as well as foliar disorders.

These factors measured were defined as follows:

Height: height in cm from pot rim to tip of tallest leaf

Fresh weight: weight in grams of the entire plant, including roots

Stem caliper: stem diameter in mm, measured at the pot rim

Number of roots: number of roots longer than 2 cm

Percent roots: visual estimate of the percentage of the pot surface area occupied by roots

Total number of leaves: total number of fully expanded leaves

Number of old leaves: number of leaves fully expanded at the initiation of the experiment

Number of new leaves: total number of leaves minus number of old leaves

Number of leaves per shoot: total number of leaves divided by number of shoots in the multi-stemmed cultivars

Leaf area: calculated using the general formula for an elipse--area=π(1/2width)(1/2length)

Number of spots: total number of necrotic spots on leaves (Figure 1a)

Spot area: calculated using the number of spots and the average spot diameter--spot area=π(1/2 spot diameter)^2 (number of spots)

Leaves with bleaching: number of leaves showing loss of chlorophyll at the leaf tip (Figure 1b)

Percent leaves with cupping: number of leaves showing a downward cupping of the leaves (Figure 1c) divided by the number of new leaves

Figure 1a. Xanthomonas leaf spot on *Dieffenbachia amoena* 'Tropic White'.

Figure 1b. Leaf tip bleaching of *Dieffenbachia amoena* 'Tropic White'

Figure 1c. Leaf cupping of *Dieffenbachia oerstedii* 'Variegata'

Figure 1d. Dasheen Mosaic Virus on *Dieffenbachia oerstedii* 'Variegata'.

Percent leaves with virus symptoms: number of leaves showing symptoms of Dasheen Mosaic Virus (Figure 1d) divided by the number of new leaves.

Experiment I

The objective of Experiment I was to determine the effect of biuret, soluble salts and light intensity on the growth and foliar damage in Dieffenbachia amoena 'Tropic White'. Three levels of biuret and 3 levels of soluble salts were combined factorially under 2 light levels with one plant per treatment and 5 replications. This experiment was set up as a split-plot with light levels as the main plot, arranged in a Randomized Complete Block design. For the biuret and soluble salt treatments, reagent grade biuret and sodium chloride were added to the standard nutrient solution. The biuret treatments were 0 ppm (control), 2 ppm (1% of N), and 10 ppm biuret (5% of N). The soluble salt treatments were 2.5 mmhos/cm (control), 6.5 mmhos/cm and 10.5 mmhos/cm (Appendix Table 2).

The plant material was obtained from local nurserymen on September 15, 1982. Treatments were begun November 14 when the plants were well rooted. Data on height, number of leaves, leaf area and number of leaf spots were collected on March 5, 1982. Plants received their final fertilization treatment April 8, and then water was withheld to induce water stress. On April 24, the plants were watered again and data was

collected on April 27. Data collected were height, fresh weight, stem caliper, number of leaves, leaf area, number of spots and number of leaves with bleaching. Plant tissue for analysis was collected at this time. Data were analysed by analysis of variance with mean separation by Duncan's multiple range test at the 5% level.

Experiment II

The objective of Experiment II was to determine the effect of the source of nitrogen on the growth and foliar damage in Dieffenbachia oerstedii 'Variegata'. Three sources of nitrogen were used: nitrate, from potassium and calcium nitrate, ammonia, from ammonium sulfate, and urea. Nutrient solutions contained 200 ppm nitrogen and potassium, 65 ppm phoshporus, 196 ppm calcium, 228 ppm sulfur and 50 ppm magnesium (Appendix Table 3). Soluble salts were adjusted to 3.1 mmhos/cm and pH to 5.9 as noted previously. Tip cuttings 30 cm in length were potted on September 6, 1981. The experiment began November 14, with 5 replications of 3 treatments. On February 20, 1982, data was collected on height, fresh weight, percent roots, number of leaves, leaf area, percent leaves with cupping and percent leaves with virus symptoms. Tissue analysis was performed at this time. Data were analysed by analysis of variance with mean separation by Duncan's mulitple range test at the 5% level.

Five Dieffenbachia cultivars were grown with the same nitrogen

sources to extend these results to other species. Three tip cuttings each of D. oerstedii 'Variegata' , D. maculata 'Surperba', D. amoena, D. amoena 'Tropic White' and D. maculata 'Key West' were potted on February 27, 1982. On April 28 the nitrogen source experiment was begun using the same treatments as above. Data on the percent leaves with cupping was collected on June 21, 1982.

Experiment III

The object of Experiment III was to determine the effect of calcium and soluble salts on the growth and foliar damage in Dieffenbachia maculata 'Perfection Compacta'. Three levels of calcium and 3 levels of soluble salts were combined in a factorial experiment. The calcium treatments were 0 ppm, 200 ppm and 400 ppm calcium. Soluble salt treatments were 2.5 mmhos/cm, 6.5 mmhos/cm and 10.5 mmhos/cm. The standard nutrient solution was used with calcium nitrate replaced by sodium nitrate in the low calcium treatment and calcium chloride added for the high calcium treatment (Appendix Table 4). The soluble salt levels were adjusted using sodium chloride.

Fifteen cm tip cuttings of D. maculata 'Perfection Compacta' were potted into 5x5x10 cm pots on November 28, 1981. Treatments were begun January 29, 1982, with 45 of the most vigorous plants. Data on height, fresh weight, number of leaves, number of roots, and leaf spots were collected on April 24 when the experiment was terminated. The data were

analysed by analysis of variance with mean separation by Duncan's multiple range test at the 5% level.

Experiment IV

The object of Experiment IV was to determine the proper leaf to use in sampling for tissue analysis. Dieffenbachia amoena 'Tropic White' were grown with 3 levels of the standard nutrient solution: 1/4 of standard (50 ppm N and K), standard (200 ppm N and K) and 7/4 of standard (350 ppm N and K) (Appendix Table 5).

Cuttings were potted on September 15, 1981. After 2 months they were well rooted, and were grown on with no nutrient additives until the experiment started on February 24, 1982. This provided material of uniformly low tissue composition for the experiment.

On May 8, the experiment was terminated and data were collected on height, number of leaves and leaf area. The first through fourth fully expanded leaves from the terminal (leaf sampling position one through four) were collected at this time and submitted as single leaf samples for tissue analysis. Data was analysed by analysis of variance with mean separation by Duncan's multiple range test at the 5% level.

RESULTS

Experiment I

Preliminary data were collected on March 5, to determine the effects of soluble salts and biuret before the plants were subjected to water stress.

Best growth was obtained at the lowest soluble salt level (Table 1). Although only height and number of new leaves showed significant differences with the soluble salt level, all growth measurements were greatest at 2.5 mmhos/cm and lowest at 10.5 mmhos/cm.

The biuret treatments produced significant growth differences only in the number of new leaves produced. The 10 ppm biuret treatment produced significantly fewer leaves than the 2 ppm or control treatments.

Prior to subjecting the plants to water stress, there were no significant differences in the foliage disorders measured, although trends were observed (Table 2). An orange-red leaf spot identified as Xanthomonas, was more prevalent under higher levels of soluble salts. Bleaching of leaf tips increased with increasing amounts of biuret.

After imposition of water stress, greater differences were found in growth measurements due to soluble salts and biuret (Table 3). While differences in growth measurements were observed for light levels, these

Table 1. Effect of soluble salts and biuret on height, leaf count and leaf area of Dieffenbachia amoena 'Tropic White' after 16 weeks.

Treatment	Height (cm)	Number of Leaves	New Leaves	Old Leaves	Leaf Area (cm^2)
Soluble Salts (mmhos/cm)					
2.5	67.8a[z]	7.0a	3.5a	3.6a	2642a
6.5	65.1ab	6.8a	3.2b	3.5a	2464a
10.5	63.5b	6.6a	3.1b	3.5a	2299a
Biuret (ppm)					
0	65.2a	6.9a	3.4a	3.5a	2603a
2	64.7a	6.8a	3.4a	3.4a	2394a
10	66.6a	6.7a	3.0b	3.7a	2408a

[z]Means in the same column followed by the same letter do not differ significantly at the 0.05 level by DMRT.

Table 2. Effect of soluble salts and biuret on leaf bleaching and Xanthomonas leaf spots of Dieffenbachia amoena 'Tropic White' after 16 weeks.

Treatment	Number of Leaf Spots	Spot Area (cm^2)	Leaves with Bleaching
Soluble Salts (mmhos/cm)			
2.5	1.5a[z]	39.6a	3.1a
6.5	2.5a	74.9a	3.7a
10.5	2.7a	64.3a	3.4a
Biuret (ppm)			
0	2.5a	66.6a	3.0a
2	2.0a	37.6a	3.4a
10	2.3a	74.6a	3.8a

[z]Means in the same column followed by the same letter do not differ significantly at the 0.05 level by DMRT.

Table 3. Effect of soluble salts, biuret and light on height, fresh weight, stem caliper, leaf count and leaf area of Dieffenbachia amoena 'Tropic White' after 23 weeks.

Treatment	Height (cm)	Fresh Wt (g)	Stem Caliper	Number of Leaves	Old Leaves	Leaf Area (cm^2)
Soluble Salts (mmhos/cm)						
2.5	63.9a[z]	374.3a	31.9a	5.3b	0.6c	2377a
6.5	60.6b	383.6a	32.4a	6.1a	1.4b	2555a
10.5	58.7c	365.8a	32.0a	6.5a	1.9a	2525a
Biuret (ppm)						
0	62.3a	381.7a	32.3a	6.1a	1.2a	2660a
2	60.2b	368.7a	32.8a	5.9a	1.2a	2360b
10	60.7ab	373.3a	31.2b	5.9a	1.4a	2437b
Light (ft-c)						
3400	61.7	370.8	31.4	6.1	1.5	2542
6000	60.5	378.3	32.7	5.9	1.0	2430

[z]Means in the same column followed by the same letter do not differ significantly at the 0.05 level by DMRT.

could not be tested by analysis of variance due to the experimental design. T-tests showed the high light treatment to have significantly larger stem caliper but fewer old leaves (Appendix Table 11).

Plant height decreased as the level of soluble salts increased. After imposition of water stress, a reversal of trends occurred such that the total number of leaves and the number of old leaves retained on the plant increased with increasing soluble salt level. Stem caliper and total leaf area increased with soluble salt level, but the differences were not significant.

Higher levels of biuret caused significant decreases in plant height and total leaf area. The total number of leaves and number of new leaves decreased with increasing levels of biuret, but not significantly.

Xanthomonas leaf spots were more prevalent in the higher soluble salt treatments, but differences were not significant (Table 4, Figure 2). Bleaching symptoms increased significantly with both soluble salt and biuret levels. Significant interactions occurred between soluble salts, biuret and light levels (Figures 3-5). High levels of soluble salts tended to cause bleaching at all levels of biuret or light, though more so at the higher levels. Biuret caused bleaching only at the higher levels of soluble salts. Higher light levels increased the incidence of bleaching at all levels of biuret or soluble salts.

Rising levels of soluble salts caused significant decreases in tissue N, P, Ca, and Mg, but increases in K, Mn, Zn and sodium (Table 5). Biuret treatments produced no significant differences in plant

Table 4. Effect of soluble salts, biuret and light on leaf bleaching and Xanthomonas leaf spots of Dieffenbachia amoena 'Tropic White' after 23 weeks.

Treatment	Number of Leaf Spots	Spot Area (cm^2)	Leaves with Bleaching
Soluble Salts (mmhos/cm)			
2.5	1.7a[z]	94.5a	0.1c
6.5	2.3a	204.0a	0.6b
10.5	3.1a	219.5a	1.5a
Biuret (ppm)			
0	1.9a	142.1a	0.4c
2	3.0a	230.4a	0.7b
10	2.2a	145.5a	1.2a
Light (ft-c)			
3400	1.9	119.5	0.4
6000	2.8	225.8	1.1

[z]Means in the same column followed by the same letter do not differ significantly at the 0.05 level by DMRT.

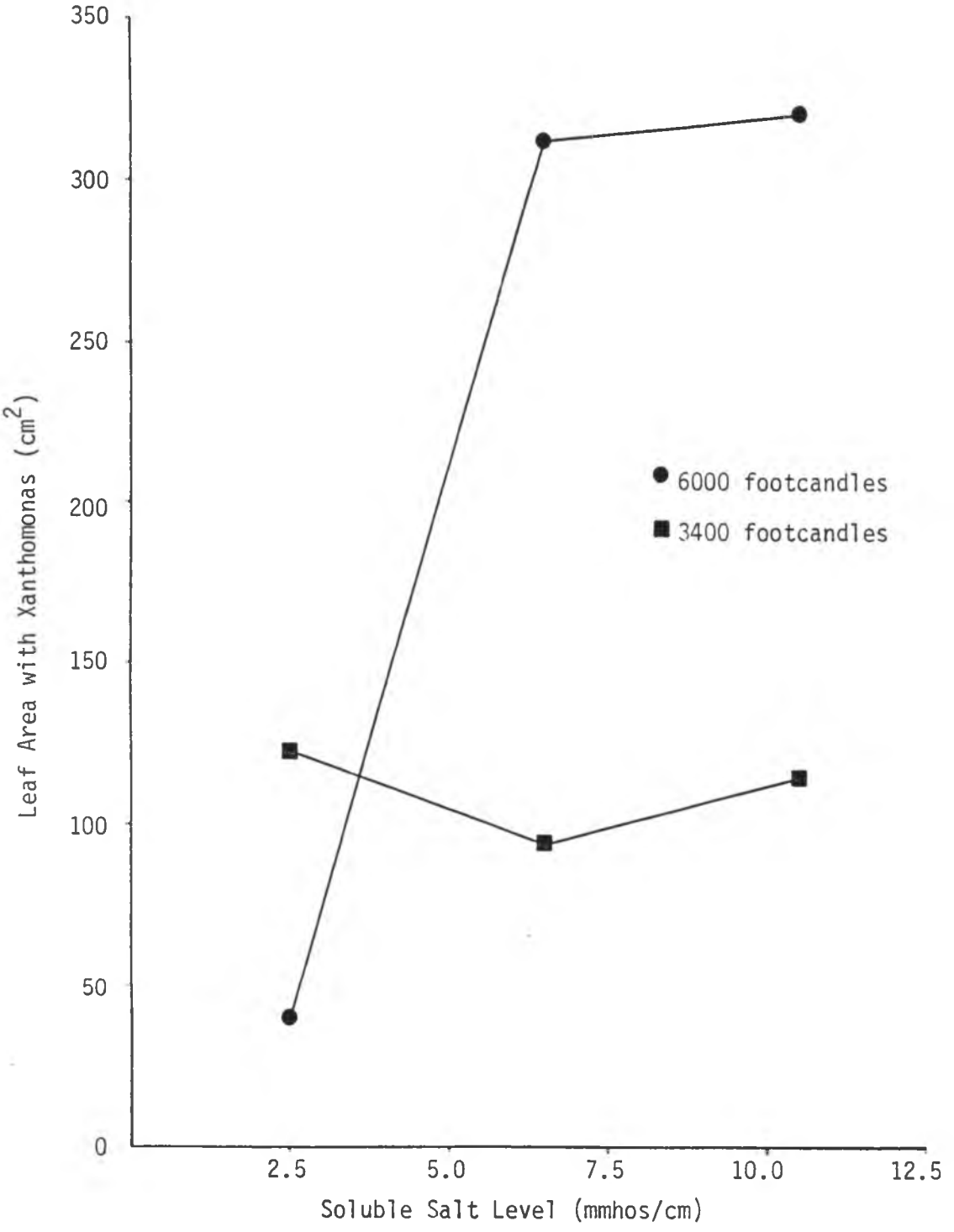

Figure 2. Effect of 3 levels of soluble salts on leaf area infected with Xanthomonas in Dieffenbachia amoena 'Tropic White' at two light levels.

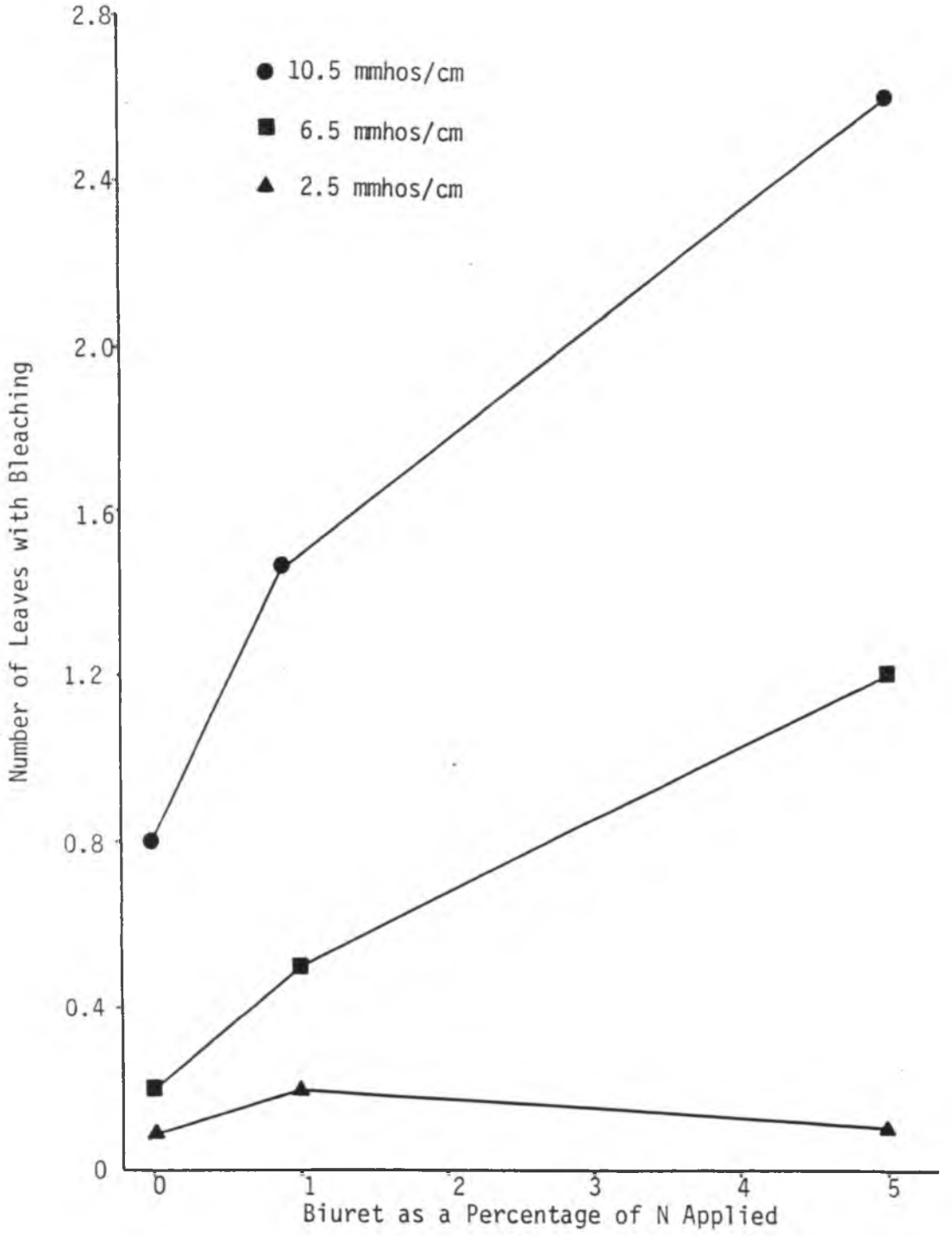

Figure 3. Effect of 3 levels of biuret on leaf bleaching in Dieffenbachia amoena 'Tropic White' at 3 soluble salt levels.

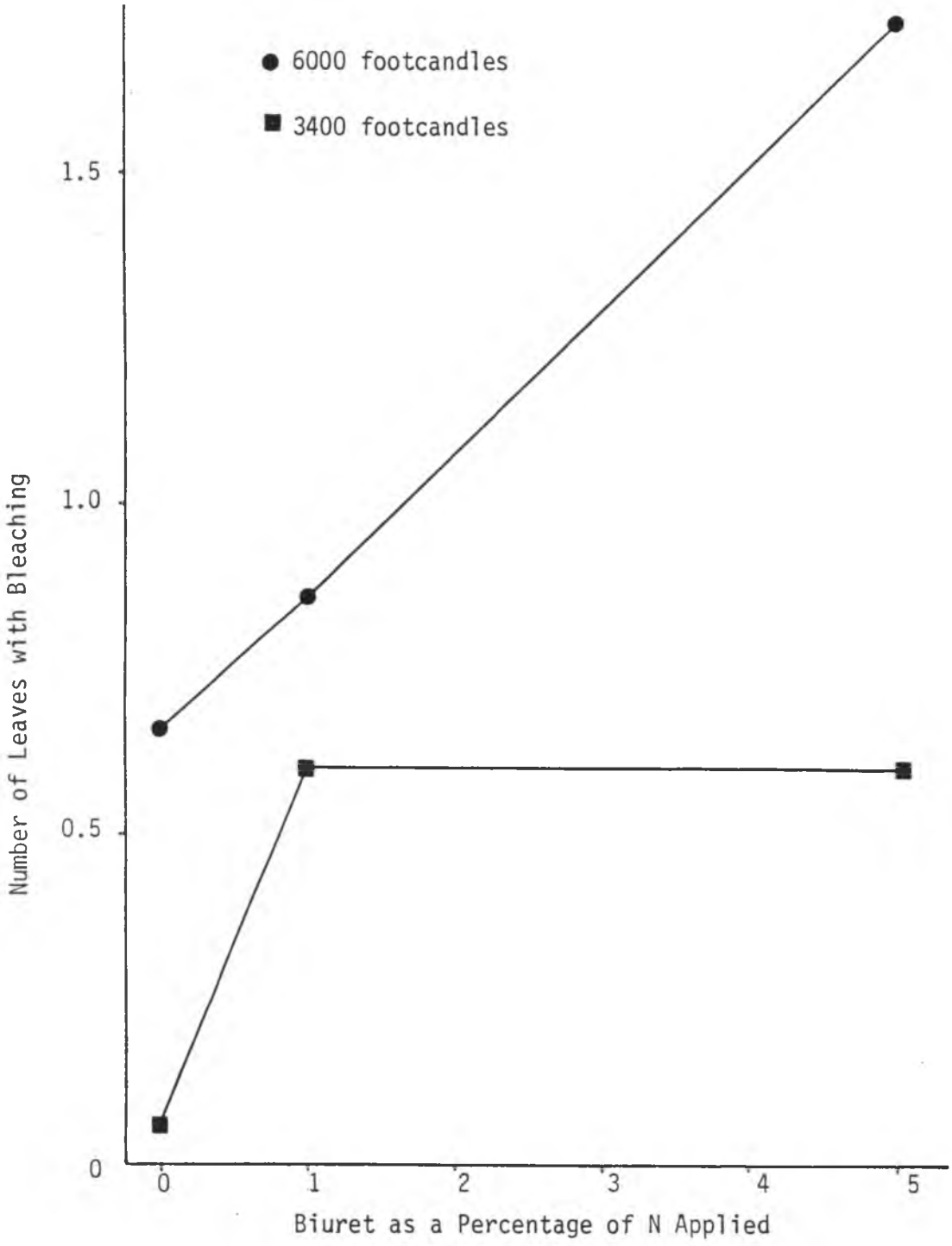

Figure 4. Effect of 3 levels of biuret on leaf bleaching in Dieffenbachia amoena 'Tropic White' at 2 light levels.

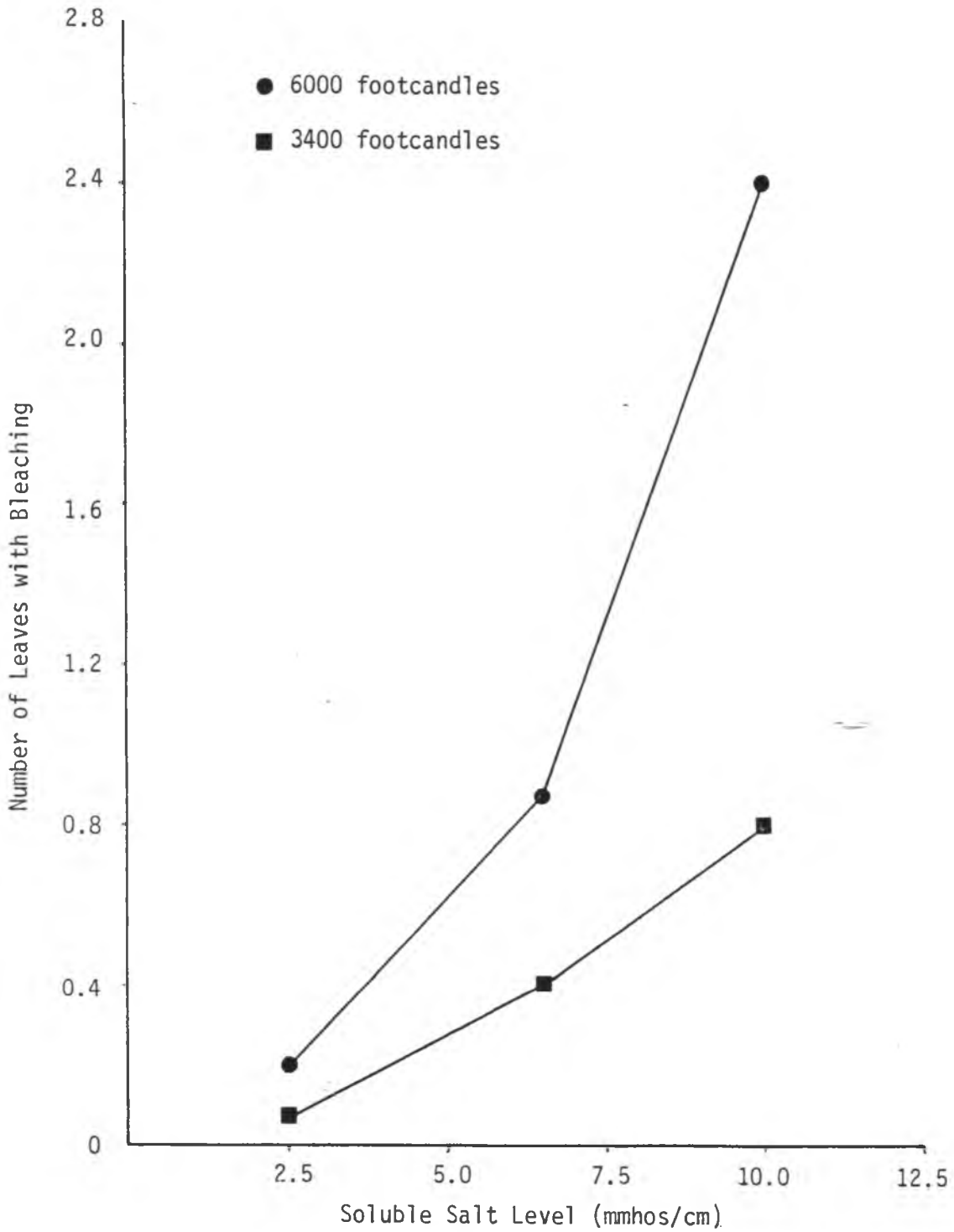

Figure 5. Effect of 3 soluble salt levels on leaf bleaching in Dieffenbachia amoena 'Tropic White' at 2 light levels.

Table 5. Effect of soluble salts on leaf tissue composition of *Dieffenbachia amoena* 'Tropic White' after 23 weeks.

Tissue Content (DW)	Soluble Salt Level		
	2.5 mmhos/cm	6.5 mmhos/cm	10.5 mmhos/cm
(percent)			
Nitrogen	2.82a[z]	2.70b	2.65b
Phosphorus	0.38a	0.33b	0.31c
Potassium	4.82b	5.20a	5.07a
Calcium	1.62a	1.26b	0.93c
Magnesium	0.58a	0.41b	0.32c
Sulfur	0.32a	0.33a	0.30a
Sodium	0.10c	0.47b	0.69a
(ppm)			
Manganese	124a	148a	141a
Iron	128a	120a	113a
Copper	29a	44a	43a
Zinc	210b	232a	200b

[z]Means in the same row followed by the same letter do not differ significantly at the 0.05 level by DMRT.

tissue elemental concentrations (Table 6).

Strong negative correlations were found between the tissue Na level and the levels of P (-.67), Ca (-.76) and Mg (-.92). Na correlated well with the incidence of bleaching (.56).

Experiment II

Plant height was significantly greater in the nitrate treatment than in the ammonia or urea treatments (Table 7). Orthogonal comparisons of treatments showed that the greatest difference was between nitrate and the two other treatments (Appendix Table 13).

Plant fresh weight, percent roots and number of new leaves followed a similar pattern. Nitrate fertilization produced the greatest fresh weight, percent roots and number of new leaves. The ammonia treatment was poorest in growth, with urea intermediate. Orthogonal comparisons showed significant differences between both urea and ammonia, and between nitrate and the other treatments.

Leaf area showed significant differences between all treatments. Nitrate fertilization produced the largest increase in leaf area, with urea fertilization producing 75% and ammonia fertilization 46% of this increase.

Two foliar disorders were observed during the course of this experiment. A disorder characterized by small, thickened, downward cupped leaves with raised veins occurred only in the ammonia and urea

Table 6. Effect of biuret on leaf tissue composition of Dieffenbachia amoena 'Tropic White' after 23 weeks.

Tissue Content (DW)	Biuret Concentration		
	0 ppm	2 ppm	10 ppm
(percent)			
Nitrogen	2.72a[z]	2.67a	2.79a
Phosphorus	0.35a	0.33a	0.34a
Potassium	5.03a	4.94a	5.12a
Calcium	1.29a	1.27a	1.25a
Magnesium	0.43a	0.44a	0.44a
Sulfur	0.32a	0.32a	0.32a
Sodium	0.41a	0.42a	0.43a
(ppm)			
Manganese	128a	153a	132a
Iron	123a	117a	122a
Copper	42a	38a	38a
Zinc	222a	209a	211a

[z]Means in the same row followed by the same letter do not differ significantly at the 0.05 level by DMRT.

Table 7. Effect of nitrogen source on height, fresh weight, percent roots, leaf count, leaf area, percent leaves with cupping, and percent leaves with virus symptoms of Dieffenbachia oerstedii 'Variegata'.

	Nitrate	Ammonia	Urea
Height (cm)	70.2a[z]	64.5b	64.2b
Fresh Wt (gm)	351.0a	234.6b	305.8a
Percent Roots	81.0a	42.0b	73.0a
Total number of Leaves	9.0a	6.4b	9.0a
Number of Old Leaves	5.6a	4.4a	6.0a
Number of New Leaves	3.4a	2.0b	3.0a
Percent Leaves with Cupping	0.0b	90.0a	93.4a
Percent Leaves with Virus	13.2a	20.0a	33.2a
Leaf Area (cm^2)	607.0a	278.8c	441.1b

[z]Means in the same row followed by the same letter do not differ significantly at the 0.05 level by DMRT.

treatments. Color break symptoms of Dasheen mosaic virus occurred more frequently in the ammonia and urea treatments, but not significantly so.

The nitrogen source produced some significant differences in mineral tissue compostition. Total nitrogen was highest under nitrate fertilization, but only differed significantly from the ammonia source (Table 8). Nitrate levels were significantly higher in the nitrate treatment than in ammonia or urea treatments. Nitrate fertilization produced plants with significantly higher levels of K, Mg, Mn, Fe and Zn, and significantly lower levels of Ca and S. Phosphorus was highest in the nitrate treatment, but was significantly different from the urea treatment only.

Average new leaf area produced significant correlations with height (.58), fresh weight (.57) and percent roots (.52). Plant height correlated well with the tissue levels of P (.68), K (.58), Mg (.54), Mn (.74) and Zn (.62). Cupping produced negative correlations with phosphorus (-.51), K (-.77), Mg (-.88) and Mn (-.56).

In the second part of this experiment, smaller cupped leaves were evident in the ammonia and urea treatments after 2 months. Dieffenbachia oerstedii 'Variegata' and the 2 maculata cultivars 'Key West' and 'Superba' were affected, but Dieffenbachia amoena and its cultivar 'Tropic White' showed no symptoms.

Table 8. Effect of nitrogen source on tissue composition of *Dieffenbachia oerstedii* 'Variegata'.

	Nitrate	Ammonia	Urea
(percent)			
Nitrogen	3.12a[z]	2.77b	3.00a
Nitrate	0.19a	0.14b	0.14b
Phosphorus	0.40a	0.37ab	0.35b
Potassium	5.82a	5.10b	4.80b
Calcium	0.85b	1.63a	1.40a
Magnesium	0.97a	0.61b	0.47c
Sulfur	0.49c	0.96a	0.76b
(ppm)			
Manganese	295a	173a	186b
Iron	101a	68b	74b
Copper	34a	43a	41a
Zinc	294a	122c	221b
Sodium	1040a	1000a	800a

[z]Means in the same row followed by the same letter do not differ significantly at the 0.05 level by DMRT.

Experiment III

Calcium levels significantly influenced the number of roots, fresh weight and number of leaves per shoot, but not height or total number of leaves (Table 9). In all cases, best growth was obtained at 200 ppm calcium, while 0 ppm calcium was intermediate, and 400 ppm calcium produced the poorest growth. There were no significant differences between the 0 and 400 ppm calcium treatments.

The soluble salt level in the nutrient solution caused significant differences in plant height, fresh weight, and number of leaves. With regard to plant height and fresh weight, best growth was obtained at 6.5 mmhos/cm. Better growth was observed at 2.5 mmhos/cm than at 10.5 mmhos/cm, but the difference was not significant. The number of leaves retained per pot decreased as the soluble salt level increased, but significant differences were found only between 2.5 and 10.5 mmhos/cm.

Division of the soluble salts and calcium treatment main effects for fresh weight by orthogonal comparisons showed significant quadratic trends (Appendix Table 15). Plots of fresh weight, plant height and number of roots by soluble salts at the three levels of calcium illustrated these trends, showing the middle level producing the best growth (Figures 6-8). Salinity and calcium produced significant differences in the number of leaves and number of leaves per shoot respectively, but did not produce clear trends. Plots of the number of leaves per shoot tended to produce quadratic curves, while plots of the

Table 9. Effect of calcium and soluble salts on height, number of roots, fresh weight, and leaf count of Dieffenbachia maculata 'Perfection Compacta' after 12 weeks.

Treatment	Height (cm)	Number of Roots	Fresh Weight	Total Number of Leaves	Number of Leaves/Shoot
Calcium (ppm)					
0	17.5a[z]	3.1ab	65.7ab	3.1a	1.8b
200	18.1a	4.5a	75.8a	2.8a	2.6a
400	14.8a	1.5b	53.3b	2.3a	1.6b
Soluble Salts (mmhos/cm)					
2.5	15.9b	2.7a	59.8b	3.3a	2.1a
6.5	20.0a	4.1a	83.6a	3.0ab	2.3a
10.5	14.6b	2.3a	51.4b	1.9b	1.6a

[z]Means in the same column followed by the same letter do not differ significantly at the 0.05 level by DMRT.

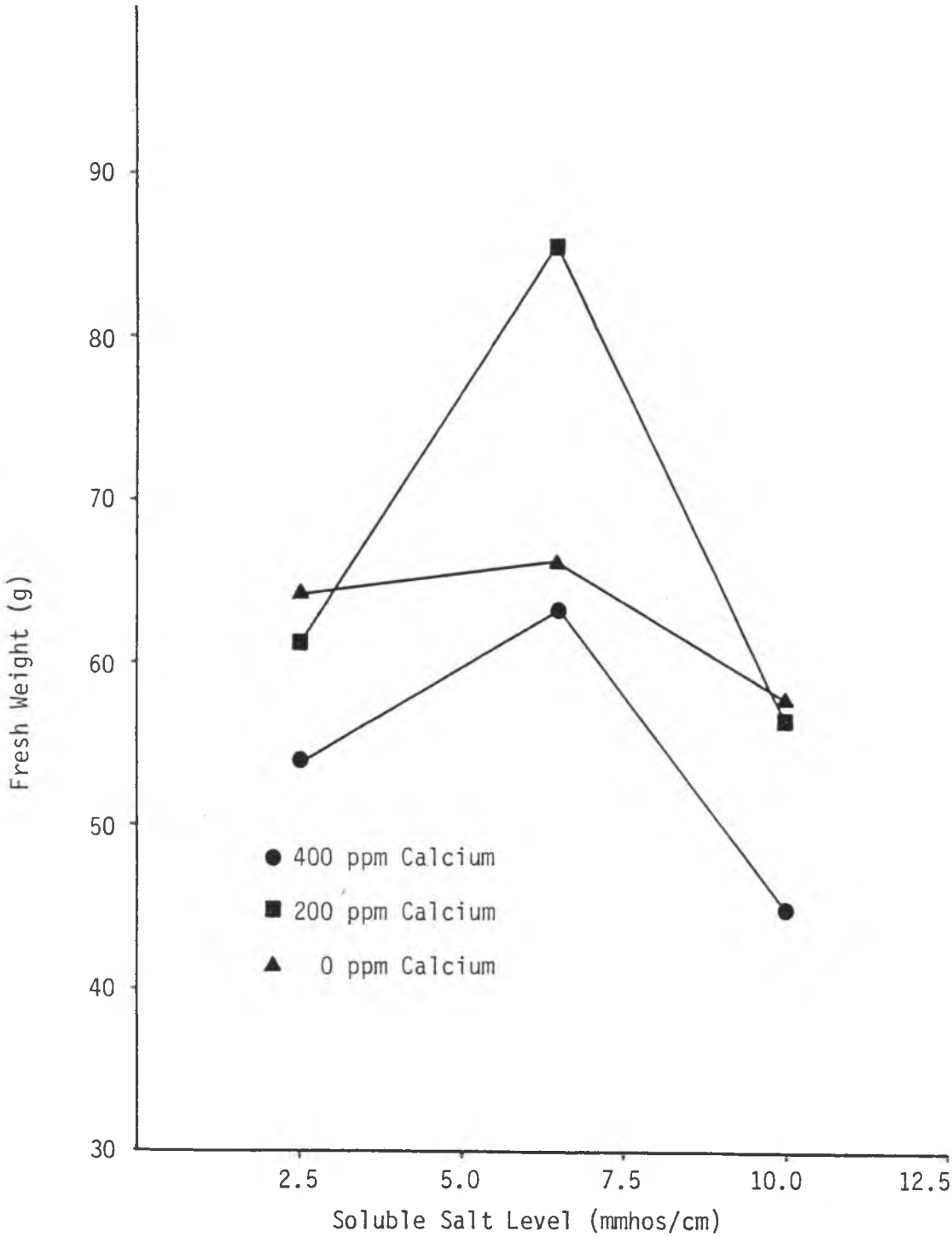

Figure 6. Effect of 3 soluble salt levels on fresh weight in Dieffenbachia maculata 'Perfection Compacta' at 3 calcium levels.

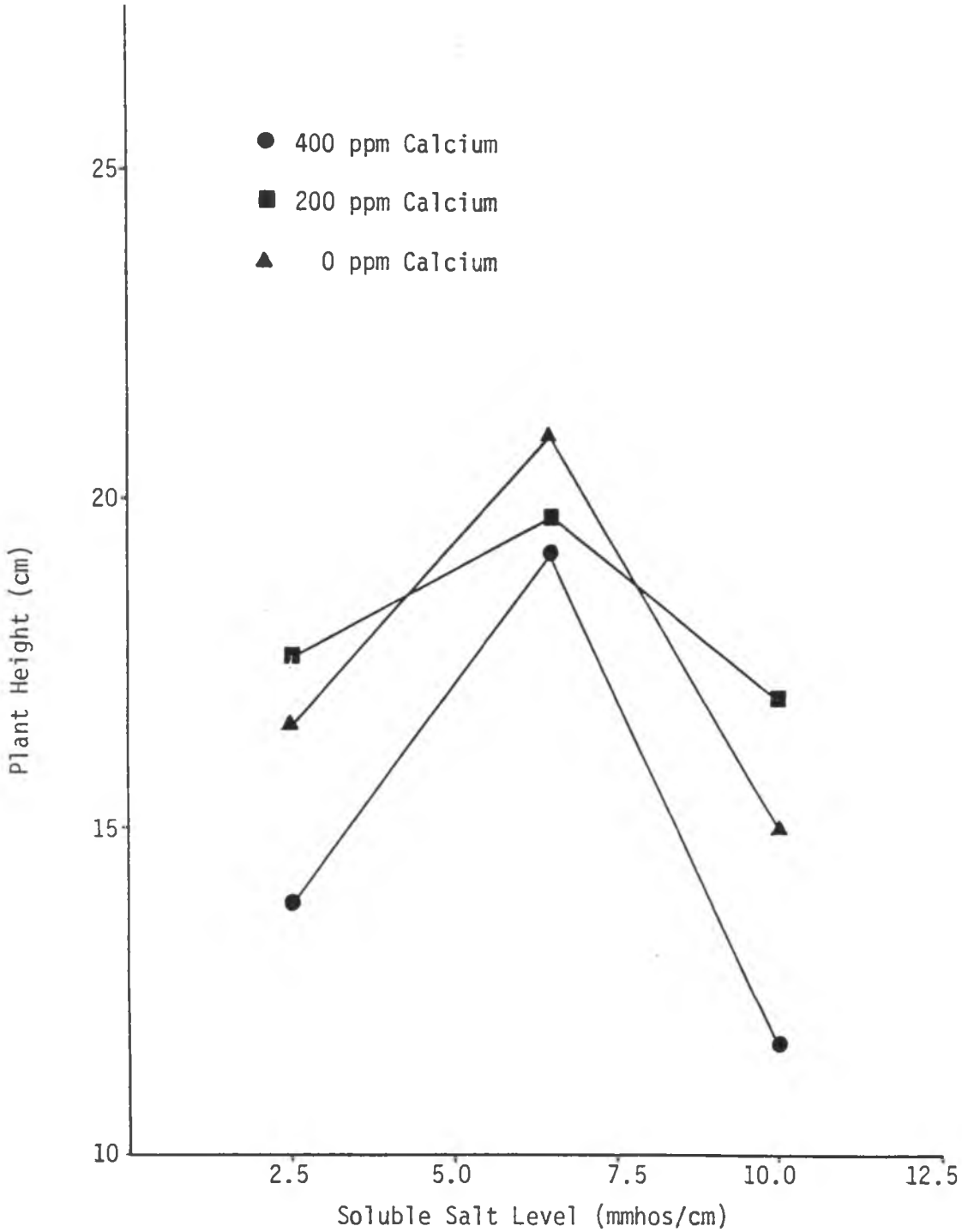

Figure 7. Effect of 3 soluble salt levels on plant height in Dieffenbachia maculata 'Perfection Compacta' at 3 calcium levels.

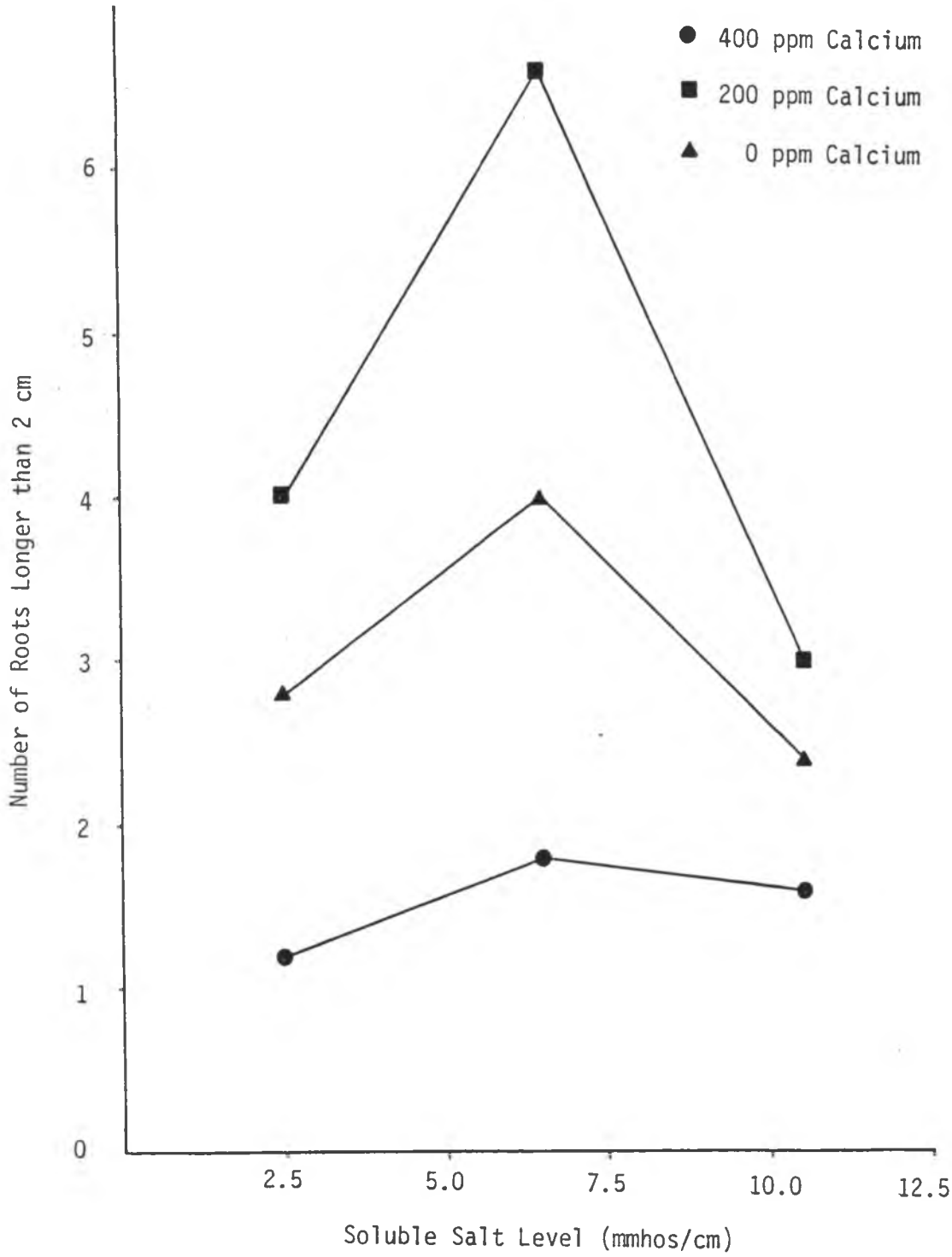

Figure 8. Effect of 3 soluble salt levels on the number of roots longer than 2 cm in Dieffenbachia maculata 'Perfection Compacta' at 3 calcium levels.

total number of leaves decreased with increases in salinity or calcium (Figures 9-10).

Experiment IV

Fertilization levels produced significant differences in the growth of Dieffenbachia amoena 'Tropic White' (Table 10). While the low fertilization level showed poorest growth in all parameters measured, the high fertilization level was significantly greater than the standard level only in the total number of leaves and leaf area.

Significant differences were found in the leaf tissue composition with changes in the fertilization level (Table 11). Tissue levels of N, P, K, Ca and S increased with increasing fertilization levels, but Mg showed no significant trends.

Comparisons between leaf sampling positions showed differences in the elemental composition (Table 12). Levels of N, P and K were highest in the youngest leaves while Mg and S were highest in the older leaves. Ca increased with leaf age, but differences were not significant.

Certain leaf sampling positions produced significant differences in the tissue elemental composition with the 3 fertilization levels (Table 11). Nitrogen levels could be distinguished using all leaf sampling positions. Significant differences were found between all fertilization levels using leaf positions 2 and 3 for K, 2 and 4 for Ca, and 4 for Mg. Plots of the leaf tissue level by the fertilization level at the 4 leaf sampling positions illustrate these trends (Figures 11-16). The best

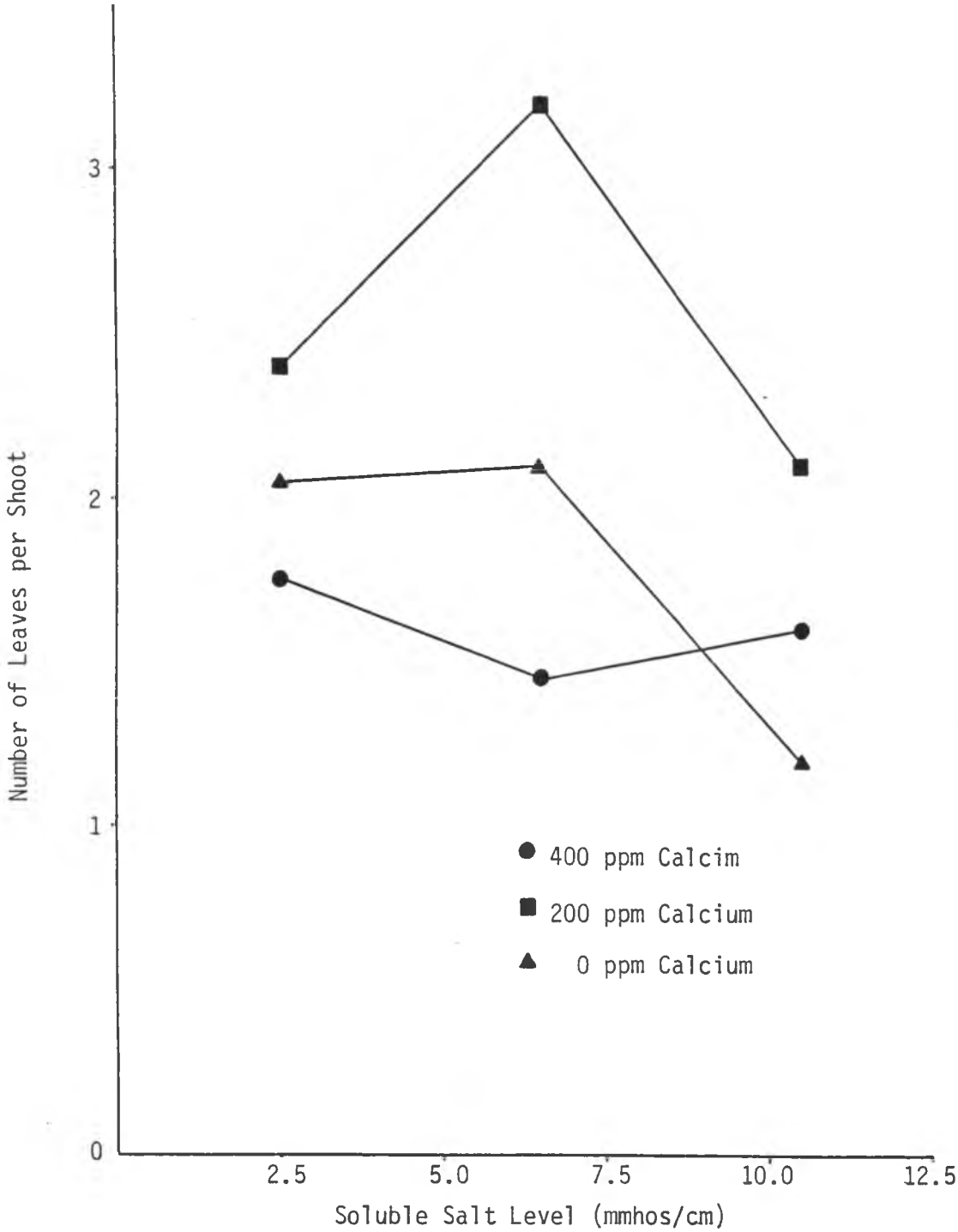

Figure 9. Effect of 3 soluble salt levels on number of leaves produced per shoot in Dieffenbachia maculata 'Perfection Compacta' at 3 calcium levels.

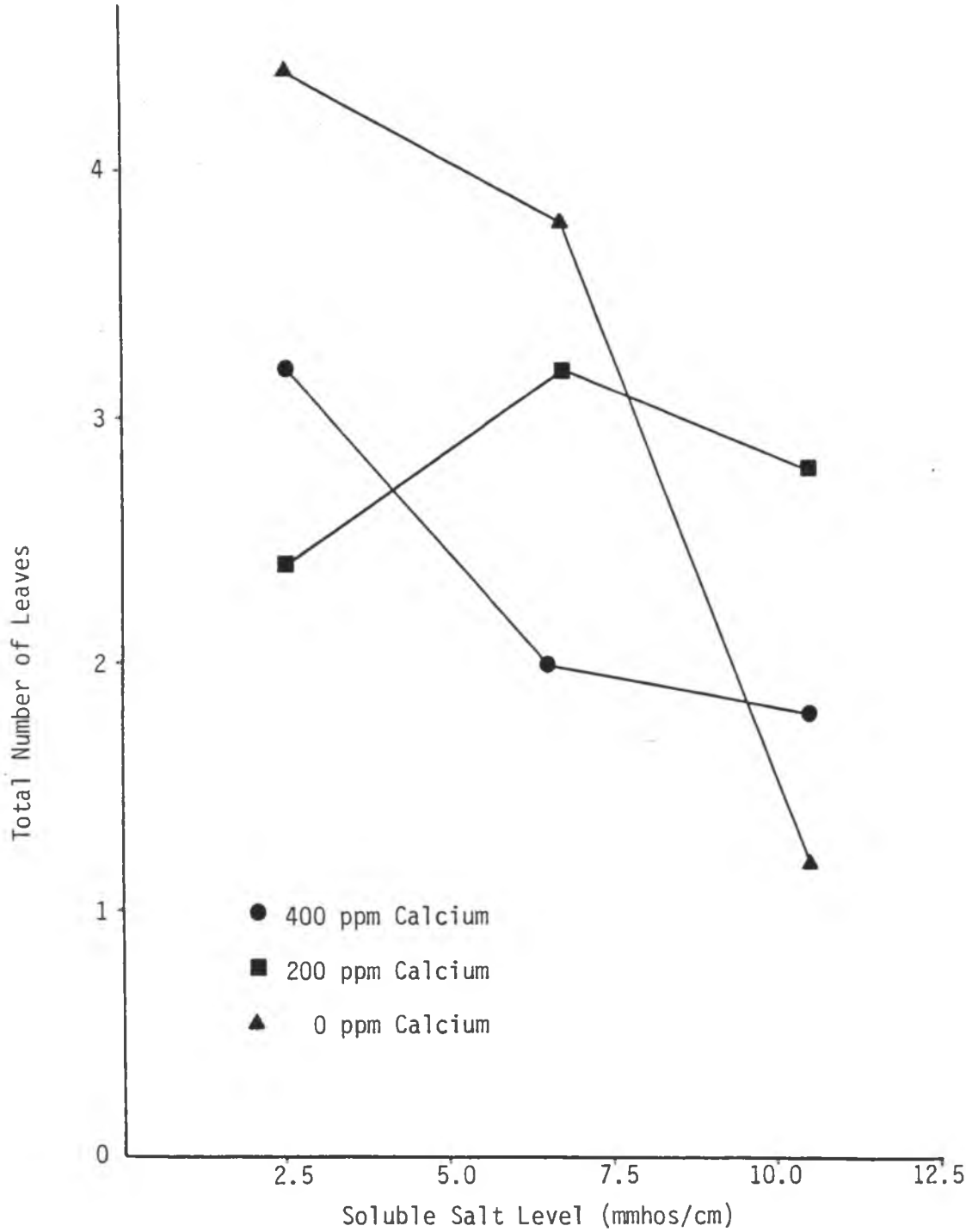

Figure 10. Effect of 3 soluble salt levels on total number of leaves in Dieffenbachia maculata 'Perfection Compacta' at 3 calcium levels.

Table 10. Effect of fertilization level on height, fresh weight, number of leaves and leaf area of Dieffenbachia amoena 'Tropic White'.

	Fertilization Level		
	1/4 of Standard	Standard	7/4 of Standard
Height (cm)	55.8b[z]	59.8a	60.2a
Fresh Weight (g)	376.0b	469.0a	476.0a
Number of Leaves	7.0c	7.2b	7.5a
Leaf Area (cm^2)	204.0c	302.0b	350.0a

[z]Means in the same row followed by the same letter do not differ significantly at the 0.05 level by DMRT.

Table 11. Effect of fertilization level on tissue composition of *Dieffenbachia amoena* 'Tropic White' at 4 leaf sampling positions.

	Fertilization Level (ppm)	Leaf 1	Leaf 2	Leaf 3	Leaf 4
Nitrogen	350	2.57a[z]	2.14a	2.03a	2.06a
	200	2.20b	1.65b	1.76b	1.77b
	50	1.20c	1.21c	1.29c	1.46c
Phosphorus	113.8	0.40a	0.36a	0.35a	0.34a
	65.0	0.35ab	0.31a	0.30b	0.28ab
	16.2	0.28b	0.28a	0.25b	0.25b
Potassium	350	4.69a	4.36a	3.17a	2.40a
	200	4.29a	3.56b	2.56b	1.91a
	50	3.71b	2.42c	1.74c	1.80a
Calcium	343	1.46a	1.32a	1.46a	1.60a
	196	1.16a	1.11b	1.17a	1.19b
	49	0.68b	0.89c	0.91a	0.68c
Magnesium	87.5	0.57a	0.49b	0.79a	0.80a
	50.0	0.57a	0.62a	0.79a	0.73b
	12.5	0.57a	0.72a	0.73a	0.48c
Sulfur	113.8	0.27a	0.27a	0.28a	0.34a
	65.0	0.29a	0.25ab	0.26a	0.31a
	16.2	0.19b	0.20b	0.26a	0.25b

[z]Means for each element in the same column followed by the same letter do not differ significantly at the 0.05 level by DMRT.

Table 12. Effect of leaf sampling position on leaf tissue composition of Dieffenbachia amoena 'Tropic White'.

	Leaf Sampling Position			
	Leaf 1	Leaf 2	Leaf 3	Leaf 4
Nitrogen	1.99a[z]	1.67b	1.70b	1.76b
Phosphorus	0.34a	0.31ab	0.30b	0.29b
Potassium	4.23a	3.45b	2.49c	2.04d
Calcium	1.10a	1.11a	1.16a	1.18a
Magnesium	0.57b	0.62b	0.77a	0.67b
Sulfur	0.25b	0.24b	0.26b	0.30a

[z]Means in the same row followed by the same letter do not differ significantly at the 0.05 level by DMRT.

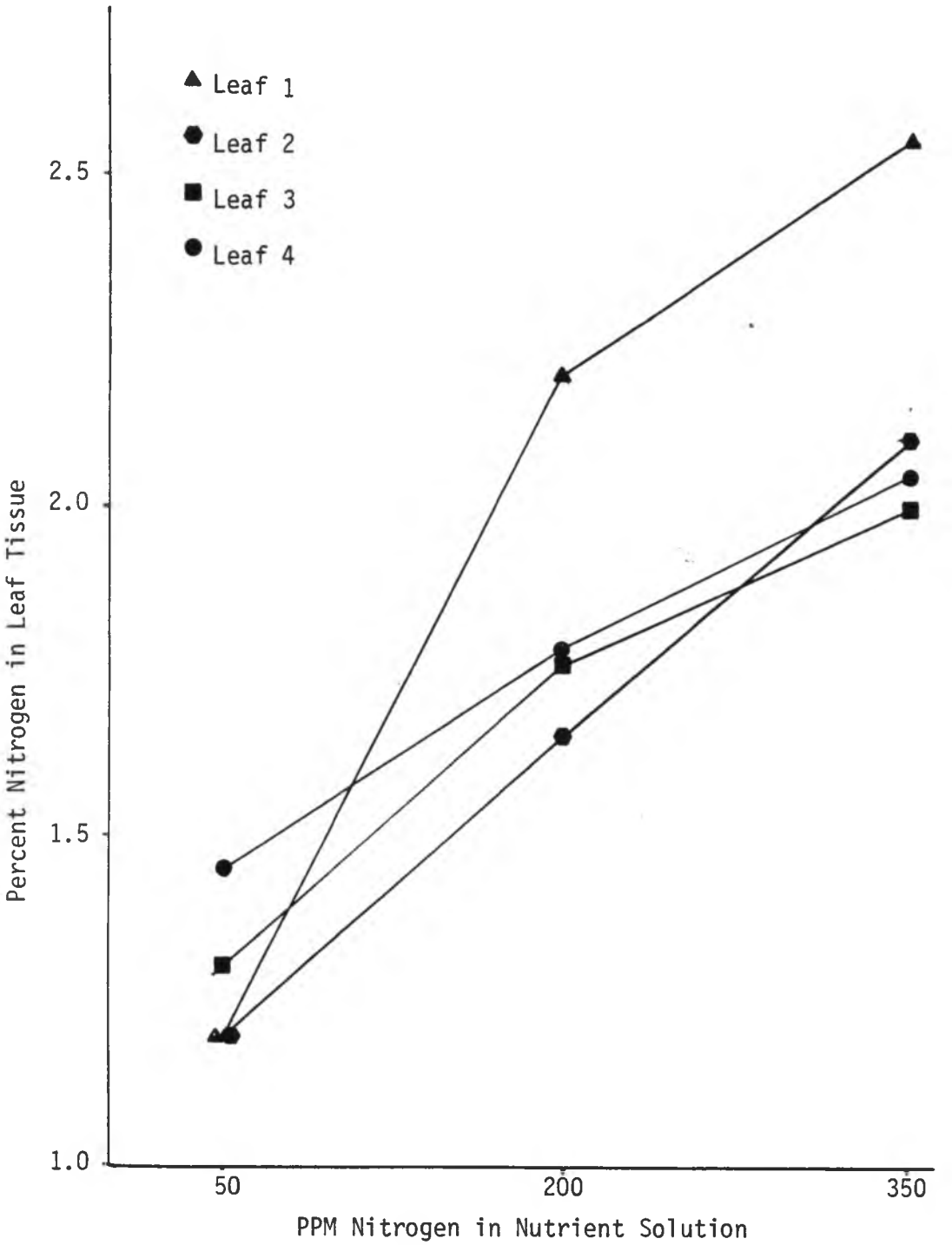

Figure 11. Effect of 3 fertilization levels on leaf tissue N level at 4 leaf sampling positions of Dieffenbachia amoena 'Tropic White'.

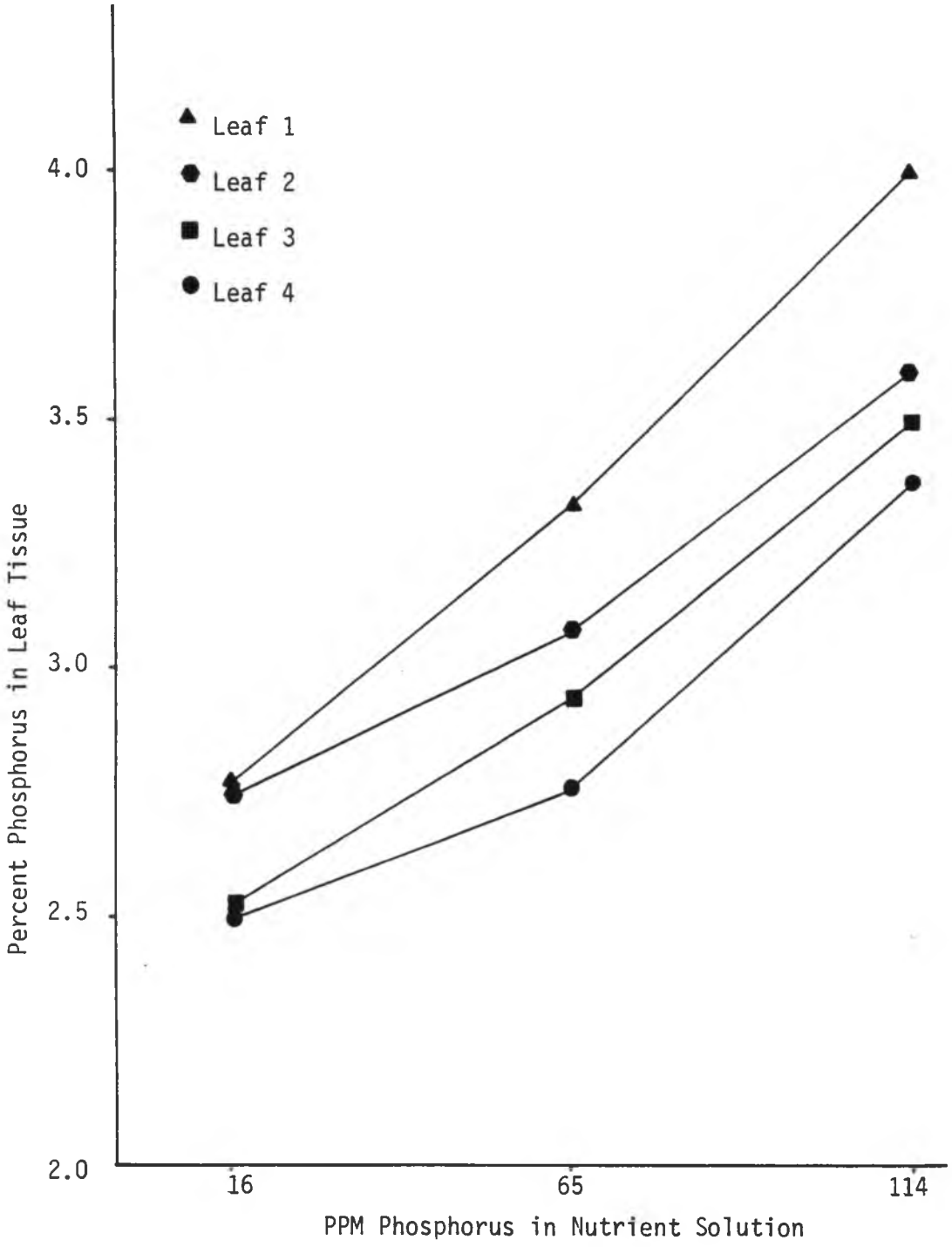

Figure 12. Effect of 3 fertilization levels on leaf tissue phosphorus of Dieffenbachia amoena 'Tropic White' at 4 leaf sampling positions.

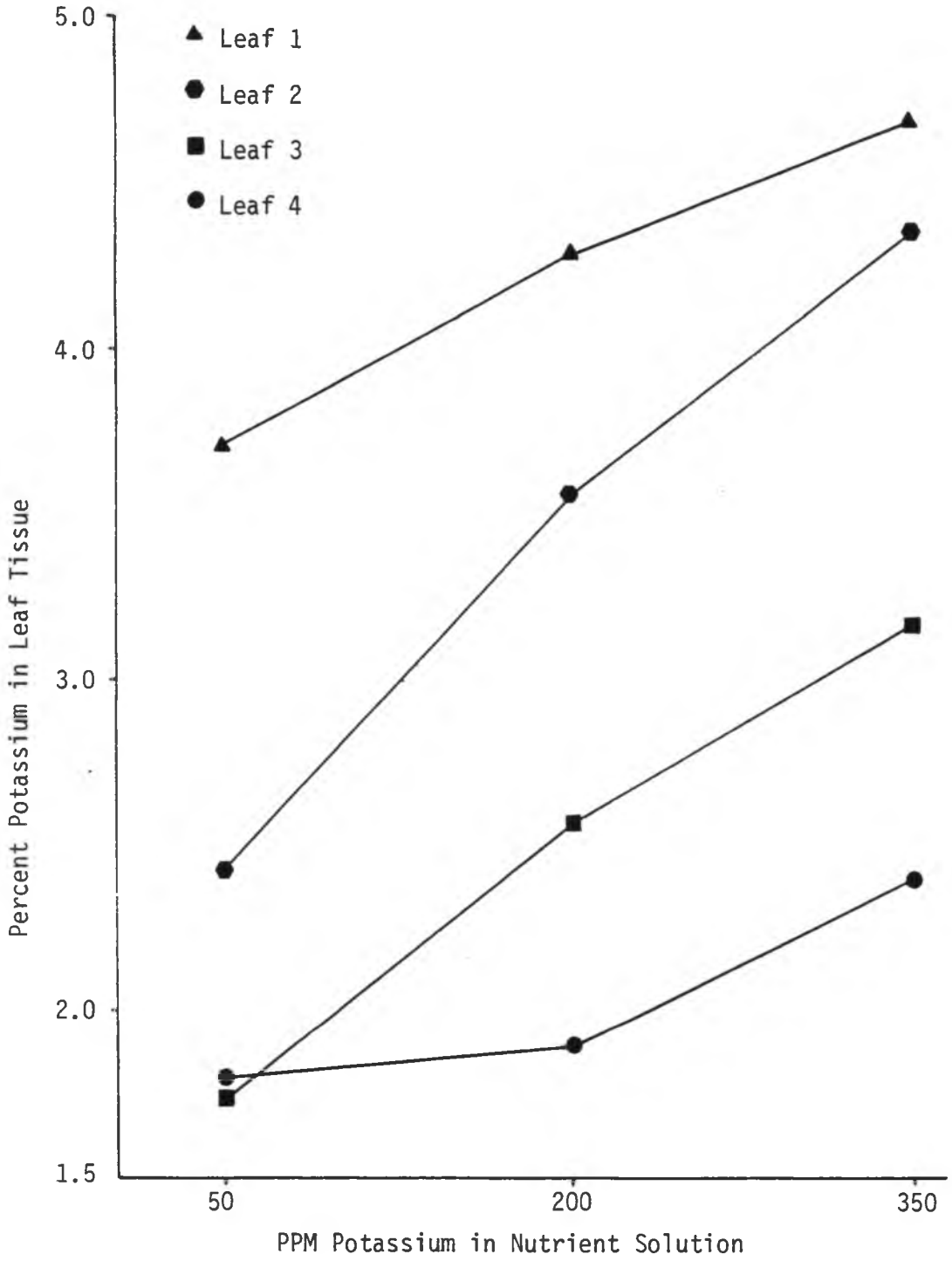

Figure 13. Effect of 3 fertilization levels on leaf tissue potassium of Dieffenbachia amoena 'Tropic White' at 4 leaf sampling positions.

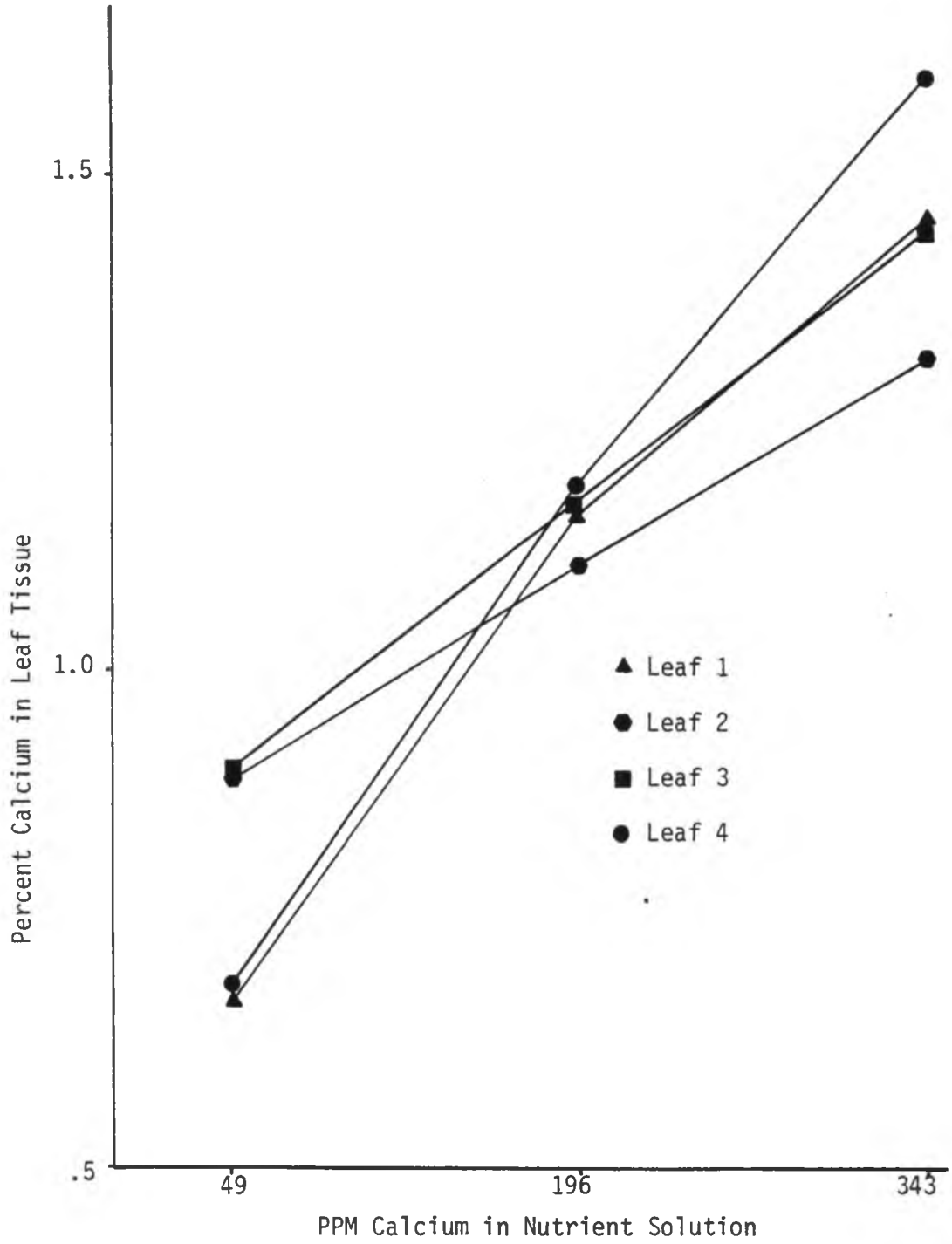

Figure 14. Effect of 3 fertilization levels on leaf tissue calcium of Dieffenbachia amoena 'Tropic White' at 4 leaf sampling positions.

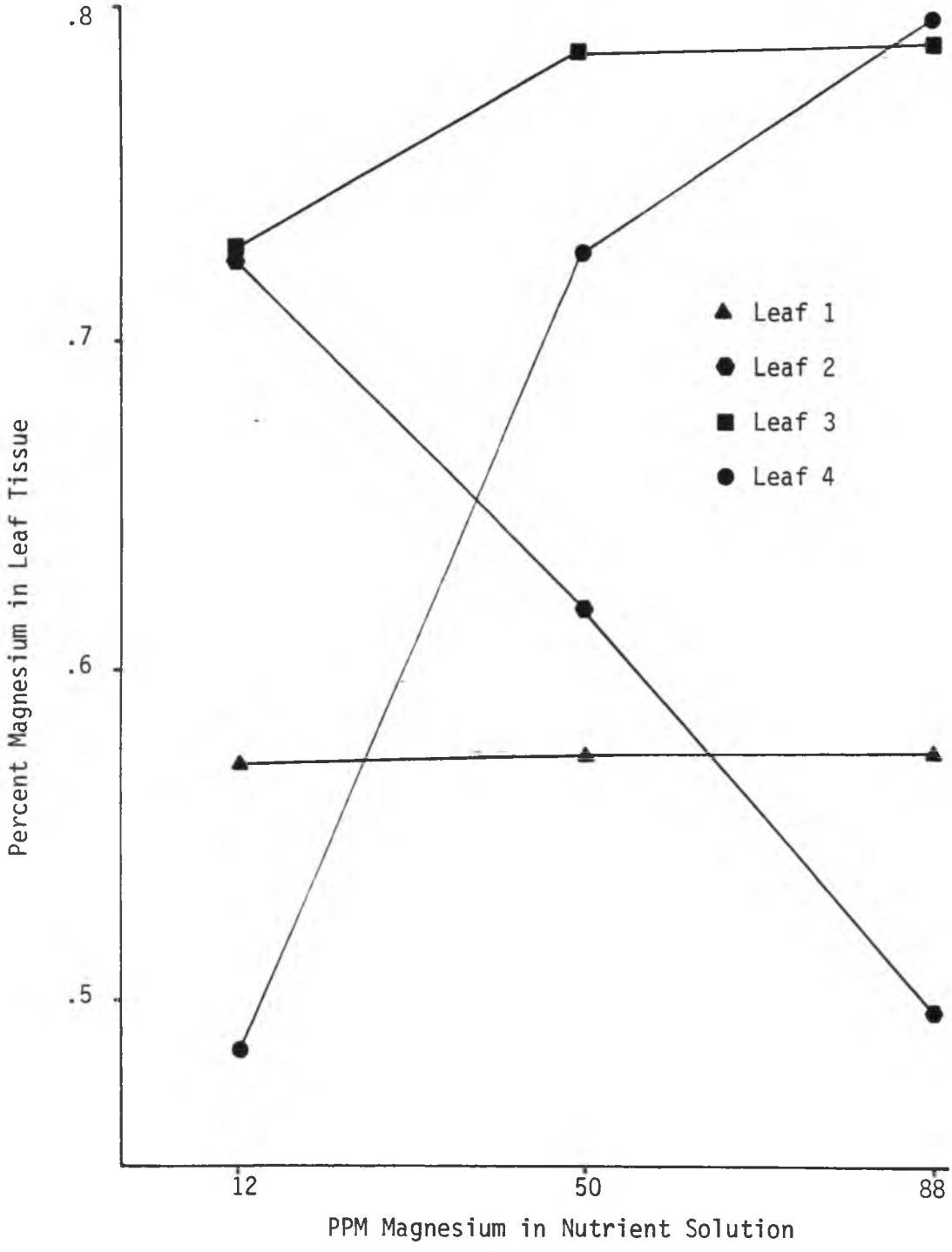

Figure 15. Effect of 3 fertilization levels on leaf tissue magnesium of Dieffenbachia amoena 'Tropic White' at 4 leaf sampling positions.

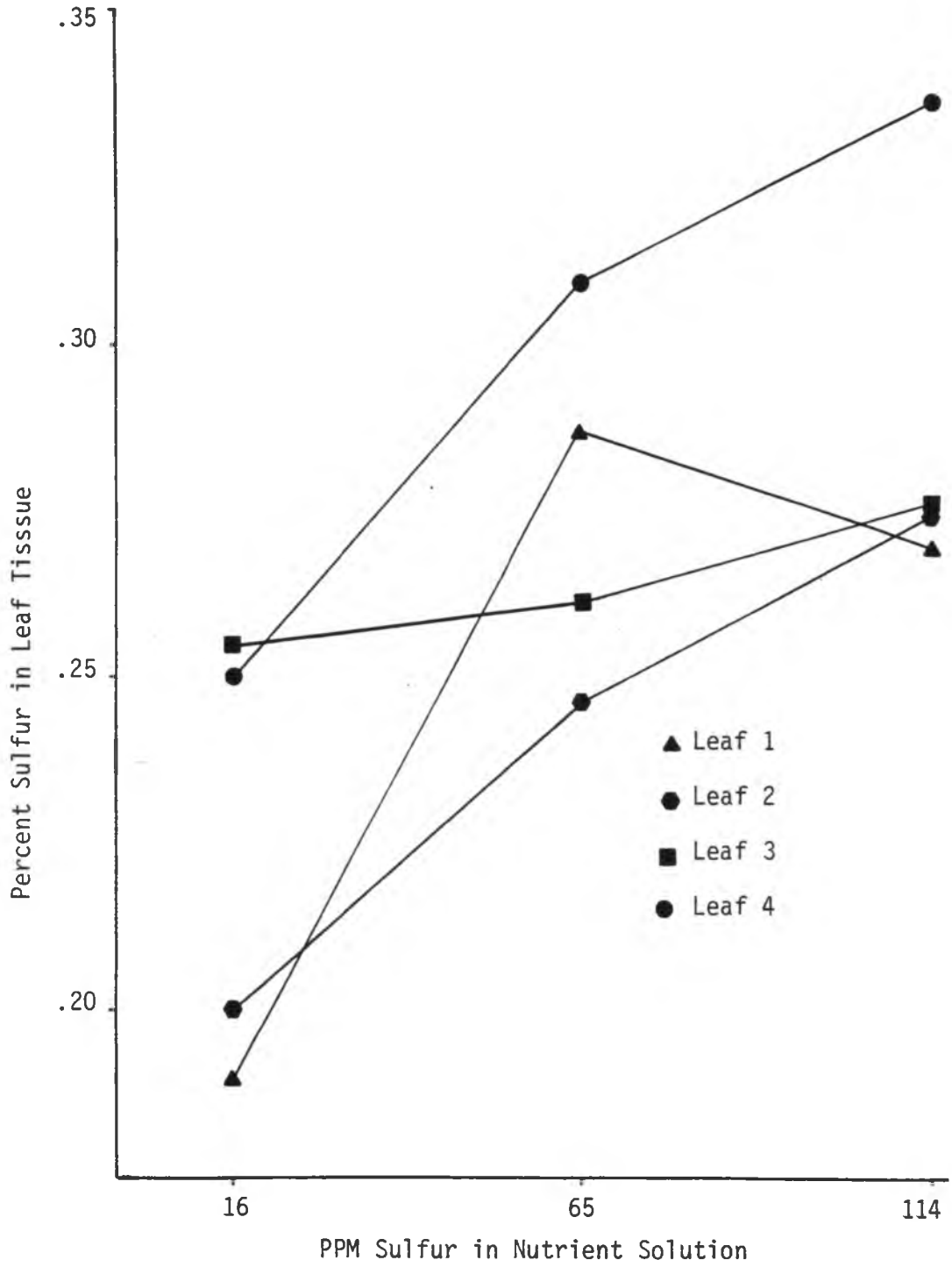

Figure 16. Effect of 3 fertilization levels on leaf tissue sulfur of Dieffenbachia amoena 'Tropic White' at 4 leaf sampling positions.

leaf positions for P and S produced significant differences only between the low fertilization level and the 2 higher levels.

Correlations were calculated to determine how closely the leaf tissue levels reflected the fertilization levels (Table 13). N levels correlate best with leaf position 1 (.95). P levels correlate best with leaf position 3 (.89), while K levels correlate best with position 2 (.97). Leaf position 4 produced the best correlations with Ca (.89), Mg (.89), and S (.81).

The coefficient of variation (C.V.) was calculated for the leaf sampling positions to measure the consistency of the tissue analysis measurements in reflecting the fertilization level (Table 14). Leaf position 3 produced the smallest C.V. for P while 2 was smallest for K. Mg and S had the smallest C.V. with leaf position 2, although all were fairly large.

Table 13. Correlation of leaf tissue composition with 3 fertilization levels at 4 leaf sampling positions in Dieffenbachia amoena 'Tropic White'.

	Leaf Sampling Position			
	Leaf 1	Leaf 2	Leaf 3	Leaf 4
Nitrogen	.95	.94	.93	.89
Phosphorus	.83	.71	.89	.74
Potassium	.87	.97	.91	.65
Calcium	.86	.85	.69	.89
Magnesium	-.02	-.80	.25	.89
Sulfur	.66	.76	.25	.81

Table 14. Coefficient of variation of nitrogen, phosphorus, potassium, calcium, magnesium and sulfur with 4 leaf sampling positions in Dieffenbachia amoena 'Tropic White'.

	Leaf Sampling Positions			
	Leaf 1	Leaf 2	Leaf 3	Leaf 4
Nitrogen	4.51%	6.92%	5.54%	8.64%
Phosphorus	13.58%	14.90%	9.00%	13.28%
Potassium	6.29%	5.86%	11.91%	16.57%
Calcium	22.16%	10.03%	25.25%	18.46%
Magnesium	12.31%	11.44%	13.88%	5.84%
Sulfur	11.57%	13.72%	18.83%	6.60%

DISCUSSION

Experiment I

The period of water stress produced some large differences in the soluble salt effects. Before stressing, the soluble salt control had the largest number of leaves and total leaf area, but after the period of water stress, it had the smallest. During the stressing period, the low salt treatments dropped up to twice as many lower leaves as the high salt treatments.

Gauch (27) observed that physical water stress is equivalent to osmotic water stress in their effects on the plant. He also noted that the osmotic pressure in the plant tissues increased after being subjected to osmotic stress. Plants preconditioned to moisture stress through a saline environment would be better able to withstand a physical water stress.

Only at the time of the final data taking were significant differences observed in plant height and total leaf area for the biuret treatments. Although unstressed controls were not available for comparison, it is probable that the period of water stress enhanced the differences due to the biuret treatments. Drying out the medium may have the effect of concentrating the biuret both in the medium and in the plant.

No new leaf spotting symptoms appeared during or after the period of water stress. The only foliar symptoms were a leaf tip bleaching and an orange-red leaf spot identified as Xanthomonas sp. by the Plant Pathology Disease Clinic.

The Xanthomonas leaf spot occurred more frequently in the high soluble salt treatment than in the controls, but not significantly so. Both the effect of the soluble salt treatment and the interaction of soluble salts with the light level were significant at the ten percent level. A plot of the leaf area infected with Xanthomonas by the soluble salt level at the two light levels showed the Xanthomonas much more prevalent at the higher light levels also (Figure 2). The added stress from high soluble salts or light may have weakened the plant and rendered it more susceptible to attack by pathogens.

Typical symptoms of biuret toxicity are bleaching or chlorosis of leaf tips (35,68). The bleaching of leaf tips observed corresponds well with this, although it was found with high light and soluble salt treatments also. Little to no bleaching was found even at the high levels of biuret, soluble salts or light when the other two treatments were at their lowest levels. However when two or more of these factors were at high levels, bleaching occurred. There may be more than one mechanism causing the same symptoms, leaf tip bleaching, but these mechansims could not be differentiated in this experiment.

Raising the level of soluble salts from 2.5 mmhos/cm to 10.5 mmhos/cm raised the tissue sodium levels to seven times that of the control. This probably had the greatest effect in altering the leaf

tissue composition under the high soluble salt levels from that of the controls. Suprisingly, the tissue levels of potassium, also a monovalent cation, were raised, and this, in turn, probably suppressed calcium and magnesium uptake. Both sodium and potassium have been shown to suppress calcium and magnesium uptake (2,27,66). No elements decreased to below their critical concentration (28,56).

In summary, significant effects have been attributed to the soluble salt and biuret treatments. Plant height was lowest in the high soluble salt treatments, but the number of leaves and total leaf area were increased over that of the controls after stressing due to the plants being preconditioned to moisture stress. Biuret caused decreases in plant height and total leaf area. Bleaching symptoms were more prevalent under high soluble salt, biuret or light levels, producing the most bleaching under high levels of two or more of the treatments. Plant tissue composition varied due to the rise in tissue sodium levels with the greater amounts of NaCl used in the soluble salts treatments.

Experiment II

There have been many reports of poorer growth with ammonia or urea nitrogen sources compared to nitrate nitrogen (4,37,38,47,54). In this experiment, the differences in root development correlated well with fresh weight (.51), total number of leaves (.64) and average new leaf area (.52), indicating a relationship between the extent of the root

system and development of the plant canopy.

All nitrogen solutions were balanced to remove pH and soluble salt differences between nitrogen sources. Sodium hydroxide and sodium chloride were used for adjusting the solutions and can be considered as having no effect as the tissue sodium levels did not differ significantly between treatments (Table 8). Throughout the experiment, the pots were heavily leached to prevent buildup of soluble salts or pH changes. Nevertheless, some pH changes occurred between each irrigation. Two days after irrigation, the nitrate and urea solutions had varied little from pH 5.9 of the starting solutions, but the ammonia solution dropped to pH 5.4.

The pH change in the ammonia solutions may be due to hydrogen ions released in the uptake of ammonium by plant roots (7). If no soil-borne organisms are available to break down urea, it can be taken up as an entire molecule and hydrolysed to ammonia inside the plant (58). This would cause no solution pH changes. It is probable that the differences in root development between the urea and ammonia fertilizer sources are caused by the pH drop in the ammonia solution. The poor root development would then explain the poorer growth with ammonia as compared with urea.

Leaf cupping symptoms were found with both urea and ammonia fertilization. As the symptoms occurred in both treatments, they are probably not related to the pH drop that occurs during ammonium uptake. These symptoms occurred on almost all leaves formed after ammonia or urea fertilization began. The percent leaves with cupping is similar

under both treatments, but because more leaves were formed under urea fertiliztion the problem appears more severe.

While there were no significant differences in the percent leaves showing virus symptoms among all treatments, the intensity of the symptoms varied markedly showing much more severe color break under urea and ammonia treatments. The severity of the color break could be due to the stress put on the plant with ammonia or urea fertilization. The incidence of virus correlated well with the levels of Mn (-.59), indicating some relationship between virus expression and lowered levels of Mn.

Lowered levels of P, K, Ca and Mg have been reported with ammonia fertilization in comparison to nitrate fertilization (4,54). In this study, the nitrate source had higher tissue levels of all elements except Ca and S. The lowered Ca levels could possibly be explained by the increases in K and Mg, which have been reported to compete with Ca for uptake (2,66). The increase in nitrate levels could be inhibiting S uptake. Kirkby and Mengel (37) found a drop in sulfate with the use of nitrate nitrogen sources.

The smaller leaved types, D. oerstedii and D. maculata, showed ammonium toxicity symptoms after 2 months of treatment. As it appears only new leaves are affected, the larger leaved species such as D. amoena would not show symptoms until later.

In conclusion, under sand culture the nitrogen form applied can produce significant differences in growth of dieffenbachia. Nitrate nitrogen produced the best growth with urea intermediate between nitrate

and ammonia. Cupping symptoms occurred only on plants with urea or ammonium. There seem to be two factors responsible for the differences observed between nitrate, urea and ammonium nutrition: 1) an unidentified toxicity factor associated with both ammonium and urea (which breaks down to ammonium) causing poor growth and leaf cupping symptoms, and 2) a pH drop observed only with ammonium uptake and associated with the poorest growth of all treatments.

Experiment III

Although tests on all plants could not be performed, symptoms indicated that all plant materials were affected by disease. Control measures (Benlate, Banrot, Agrimycin) were used, but plants still seemed very susceptible to decline in the sterile sand conditions. The decline symptoms were poor growth, poor root development and dropping of basal leaves. The Plant Pathology Disease Clinic identified Colletotrichum sp. (Anthrancnose) as the predominant fungus in all culture plates. Colletotrichum is not usually considered to be a primary pathogen of Dieffenbachia. The differences in growth observed with the soluble salt and calcium treatments may be reflecting the relative ability of these treatments to confer disease resistance or susceptibility to the plants.

Calcium has been shown to affect root tips and growth terminals first in deficiency conditions (27). The low calcium treatment would be expected to cause poor root growth and subsequent poor top growth. Root

tip dieback in a calcium deficiency would also render the plant more susceptible to attack by pathogens. 200 ppm calcium produced the best growth. Whether this is due to its nutritional capabilities or its ability to enhance resistance to disease cannot be determined. At 400 ppm calcium significantly poorer growth was found, the plant somehow being rendered more susceptible to disease.

In contrast with the results of Experiment I, best growth was obtained at the middle soluble salt level. Although most studies show a decrease in growth parameters as soluble salts increase (5,34,39), there have been cases where plant growth increased with an increase in soluble salts (25,64). Under the sand culture growth conditions, the plants were irrigated while the medium was still moist, preventing soluble salt buildup or concentration as the medium dried out. This would result in "good growth" at higher soluble salt levels than would occur in soil. For this reason, best growth occurred at levels which may cause death to sensitive plants in soil. At 10.5 mmhos/cm, though, growth was reduced and the plants were more susceptible to disease entry.

The measurements of total number of leaves and number of leaves per shoot did not produce clear trends. In this experiment, the number of leaves was not probably a good measure of the relative growth and vigor of the plants. Plants in poor condition would tend to lose their lower leaves, causing new leaves to be unfurled before they are fully developed. These leaves, while contributing to the leaf count, would not raise the photosynthetic area of the plant to any large extent due to their small size.

It is possible that the mechanisms seen here are the same as those observed under commercial culture. The tip burn and dropping of lower leaves were similar to the symptoms observed during the experiment. As both high and low levels of calcium and soluble salts produced the same symptoms and no interactions were observed, it is difficult to determine which was responsible for the symptoms observed under commercial conditions. Nevertheless, monitoring the solution calcium levels and total soluble salts could have significant effects on reducing the incidence of this tip burn in commercial practices.

Under the conditions of this experiment, best growth was obtained at 200 ppm calcium and 6.5 mmhos/cm soluble salts. Treatment levels above or below this produced poorer growth, the loss of lower leaves and poor root development. These differences could be reflecting the relative ability of the calcium and soluble salt treatments to confer a measure of disease resistance to the plants.

Experiment IV

Several criteria should be used in determining the optimum leaf sampling position for dieffenbachia tissue analysis. Those considered in this analysis are the range in elemental levels with fertilization, the correlation of the tissue elemental levels with fertilization levels, and sample to sample variation.

The range of elemental levels is one measure of the influence of

fertilization on plant tissue composition. A larger range of tissue elemental levels would mean smaller fertilization differences could be detected. The range of tissue elemental levels with fertilization for each of the leaf sampling positions can best be illustrated with plots (Figures 11-16). According to this criterion, the best leaf sampling positions are Leaf 1 for N, P and S, Leaf 2 for K, and Leaf 4 for Ca and Mg. Leaf 1, while showing the largest magnitude change in S levels, also showed a drop in S levels in the highest fertilization treatment, and so may not accurately reflect the tissue sulfur level.

Correlations were used to determine which leaf sampling position best reflected the changes in fertilization. By this criterion, Leaf 1 was best for N, Leaf 2 for K, Leaf 3 for P, and Leaf 4 for Ca, Mg and S (Table 13).

The coefficient of variation is a good indicator of the reliability of an experiment; it isolates the variation in the measurements not accounted for by any known sources. The smallest coefficient of variation indicates the most consistent measurement. According to this criterion, the most consistent leaf sampling positions are Leaf 1 for N, Leaf 2 for K and Ca, Leaf 3 for P, and Leaf 4 for Mg and S (Table 14).

Multiple range tests take into account the range of values and the variability in the measurements in dividing treatments into significantly different groups. By this criterion, N is separated equally well at all leaf positions, P is best at Leaf 3, K is best at Leaf 2 and 3, Ca is best at Leaf 2, and Mg and S are best at Leaf 4 (Table 11).

For analysis of specific elements, the choice of the optimum leaf sampling position is clear. For N, Leaf 1 is best by all criteria. For P and K Leaf 3 and 2 respectively seem best, although Leaf 1 may also be acceptable. Leaf 4 is best for analysis for Ca, Mg or S. These results are in agreement with that of most studies (8,27,40,41,52,55,59,61,63). Mobile elements such as N, P and K are best analysed using younger leaves while immobile elements such as Ca, Mg and S are best analysed with older leaves.

The Mg concentrations in the various leaf sampling positions showed confusing trends, only rising with increased Mg fertilization in Leaf 3 and 4. In Leaf 1 no change occurred while in Leaf 2 the Mg concentration decreased with increasing Mg fertilization.

Two factors may account for this observation. If the increase in Mg uptake with higher fertilization resulted in increased growth, the growth could act to decrease or hold the nutrient concentration constant in the plant. This effect has been observed in carnations with respect to Ca and Mg nutrition (53). The effect seems to be most prevalent when immobile elements are analysed using younger tissues. The increased growth of the new tissues along with the immobility of the element combine to produce unexpected analysis results. There may also be an inhibition of Mg uptake due to the increases in other cation uptake. K and Ca have been shown to inhibit Mg uptake (23,27). Although the ratios of elements remained the same, the higher cation concentrations may have inhibited Mg uptake. An experiment set up to observe the effect of changes in fertilization levels of each element separately on

tissue elemental concentration could clarify the observed changes in the Mg levels.

The best overall leaf sampling position for tissue analysis requires a compromise of the best leaves to sample for individual element analysis. The leaf sampling positions were ranked according to their measurements by the above criteria. Due to the inconsistent results of Mg in tissue analysis, it was not taken into consideration in these calculations. When considering N, P, K, Ca and S, leaf position 2 proved to be the best compromise choice, producing the most significant differences, largest range, smallest coefficent of variation and best correlations.

SUMMARY

Soluble salt and biuret treatments produced significant effects in the growth of Dieffenbachia amoena 'Tropic White'. High soluble salt levels caused a decrease in plant height. The number of leaves and leaf area retained on the plant were increased over that of the controls after two weeks of water stress due to the increased "hardiness" of the treated plants. Biuret caused decreases in plant height and total leaf area. High levels of biuret, soluble salts and light caused increases in leaf tip bleaching. Most bleaching occurred under high levels of two or more of the treatments.

Different sources of nitrogen produced significant differences in dieffenbachia growth. Plants treated with nitrate solutions produced the best growth while urea treated plants were intermediate and ammonium treated were poorest. A downward cupping of leaves occurred only on plants treated with urea or ammonium. Two factors appear to be responsible for the differences: 1) an unidentified toxicity factor associated with both ammonium and urea causing poor growth and leaf cupping, and 2) a pH drop observed with ammonium uptake associated with the poorest growth of all treatments.

Under the experimental conditions, Best growth of Dieffenbachia maculata 'Perfection Compacta' occurred with 200 ppm calcium and 6.5 mmhos/cm soluble salts. Plants subjected to treatment levels above or

below this produced poor growth, loss of lower leaves and poor root development. All plants appeared to be affected by disease. It is probable that the poorer growth at higher or lower levels of calcium and soluble salts is reflecting the relative ability of these treatments to confer a measure of disease resistance or susceptibility to the plants.

Using Dieffenbachia amoena 'Tropic White', the first fully expanded leaf from the apex was found to be best for analysis of N, P and K, while the fourth fully expanded leaf was best for Ca, Mg and S. The best single tissue for analysis of N, P, K, Ca and S was the second fully expanded leaf.

SUGGESTIONS FOR FURTHER RESEARCH

There are several areas in which further research is necessary to explain and clarify the results presented in this thesis.

Organic nitrogen sources were shown to cause toxicity symptoms when used in a sterile environment. Further studies using commercial media sources and sterilization procedures may determine if this remains a problem under commercial culture.

In Experiment III, a relationship was observed between nutrition of dieffenbachia and disease. The nature of this relationship could be clarified by using clean stock and controlled inoculation with specific pathogens.

In Experiment IV preliminary experiments were performed to determine the proper leaf to sample for dieffenbachia tissue analysis. To clarify these results and explain the inconsistent behavior of Mg in the analysis, treatments could be designed to vary the levels of each element separately. These experiments could then be expanded to observe differences in tissue analysis due to the seasons or the length of time under a specific nutrient regime. Certain elements such as calcium are known to accumulate in older tissues, but how responsive this is to the current nutrition level is unknown.

Comparisons of the control treatments for Dieffenbachia amoena 'Tropic White' show some general tissue analysis ranges:

Tissue Composition Ranges

(percent)	Hawaii	Florida
Nitrogen	2.5-3.2	2.5-3.5
Phosphorus	.30-.45	.20-.35
Potassium	4.1-5.1	3.0-4.5
Calcium	1.1-2.0	1.0-1.5
Magnesium	.45-.65	.30-.80
Sulfur	.25-.45	-
(ppm)		
Manganese	70-225	50-300
Iron	85-140	50-300
Copper	25-35	10-60
Zinc	175-240	25-200

While these figures are in general agreement with figures from Florida (28,56), a compilation of tissue analysis for Hawaii conditions would be of value to the industry. Recommendations from Florida call for reduced levels of phosphorus and potassium. This is reflected in the lowered levels in tissue analysis from Florida. Tests could also be performed to determine if "good growth" may be obtained at the lowered phosphorus and potassium levels.

Appendix Table 1. Micronutrient preparations incorporated into medium.

Nutrient	Percent in Fertilizer	PPM in Medium
Micromax at 30g/ft^3		
Iron	12	135.0
Manganese	2.5	28.0
Copper	0.5	5.6
Zinc	1.0	11.0
Boron	0.1	1.1
Molybdenum	0.005	0.056
Sulfur	15.0	169.8
Perk at 84g/ft^3		
Iron	3.7	115.0
Manganese	2.3	71.7
Copper	0.23	7.2
Zinc	0.69	21.6
Boron	0.023	0.7
Molybdenum	-	-
Sulfur	4.5	140.0

Appendix Table 2. Nutrient solution for Experiment I.

Grams/19 liters	Nutrient	Analysis
19.54	$Ca(NO_3)_2$	165.2 ppm N
		196.0 ppm Ca
5.07	KNO_3	118.0 ppm K
		34.8 ppm N
9.46	$MgSo_4$	50.0 ppm Mg
		65.0 ppm S
5.40	KH_2PO_4	82.0 ppm K
		65.0 ppm P

Soluble salt level adjusted with NaCl.

low soluble salts - 0 NaCl 2.5 mmhos/cm

medium soluble salts - 30 ml NaCl 6.5 mmhos/cm

high soluble salts - 60 ml NaCl 10.5 mmhos/cm

Biuret levels adjusted with reagent grade biuret.

low biuret - none added

medium biuret - 0.099 g/19 liters 2 ppm biuret

high biuret - 0.497 g/19 liters 10 ppm biuret

Appendix Table 3. Nutrient solution for Experiment II.

Grams/19 liters	Nutrient	Analysis
Nitrate Solution		
19.54	$Ca(NO_3)_2$	165.2 ppm N 196.0 ppm Ca
5.07	KNO_3	118.0 ppm K 34.8 ppm N
9.46	$MgSO_4$	50.0 ppm Mg 65.0 ppm S
5.40	KH_2PO_4	82.0 ppm K 65.0 ppm P
13.70	Na_2SO_4	163.0 ppm S
Ammonium Solution		
17.85	$(NH_4)_2SO_4$	200.0 ppm N 228.0 ppm S
5.40	KH_2PO_4	82.0 ppm K 65.0 ppm P
4.29	KCl	118.0 ppm K
7.87	MgCl	50.0 ppm Mg
10.29	$CaCl_2$	196.0 ppm Ca
Urea Solution		
8.22	H_2NCONH_2	200.0 ppm N
9.46	Mg_2SO_4	50.0 ppm Mg 65.0 ppm S
5.40	KH_2PO_4	82.0 ppm K 65.0 ppm P
13.70	Na_2SO_4	163.0 ppm S
4.29	KCl	118.0 ppm K
10.29	$CaCl_2$	196.0 ppm Ca

Appendix Table 4. Nutrient solution for Experiment III.

Grams/19 liters	Nutrient	Analysis
0 ppm Calcium		
19.54	$NaNO_3$	165.2 ppm N
5.07	KNO_3	118.0 ppm K 34.8 ppm N
9.46	$MgSO_4$	50.0 ppm Mg 65.0 ppm S
5.40	KH_2PO_4	82.0 ppm K 65.0 ppm P
200 ppm Calcium		
19.54	$Ca(NO_3)_2$	165.2 ppm N 196.0 ppm Ca
5.07	KNO_3	118.0 ppm K 34.8 ppm N
9.46	$MgSO_4$	50.0 ppm Mg 65.0 ppm S
5.40	KH_2PO_4	82.0 ppm K 65.0 ppm P
400 ppm Calcium		
19.54	$Ca(NO_3)_2$	165.2 ppm N 196.0 ppm Ca
5.07	KNO_3	118.0 ppm K 34.8 ppm N
9.46	$MgSO_4$	50.0 ppm Mg 65.0 ppm S
5.40	KH_2PO_4	82.0 ppm K 65.0 ppm P
10.71	$CaCl_2$	204.0 ppm Ca

Appendix Table 5. Nutrient solution for Experiment IV.

Grams/19 liters	Nutrient	Analysis
Low Nutrition		
4.88	$Ca(NO_3)_2$	41.3 ppm N 49.0 ppm Ca
1.27	KNO_3	29.5 ppm K 8.7 ppm N
2.36	$MgSO_4$	12.5 ppm Mg 16.2 ppm S
1.35	KH_2PO_4	20.5 ppm K 16.2 ppm P
Medium Nutrition		
19.54	$Ca(NO_3)_2$	165.2 ppm N 196.0 ppm Ca
5.07	KNO_3	118.0 ppm K 34.8 ppm N
9.46	$MgSO_4$	50.0 ppm Mg 65.0 ppm S
5.40	KH_2PO_4	82.0 ppm K 65.0 ppm P
High Nutrition		
32.20	$Ca(NO_3)_2$	289.1 ppm N 343.0 ppm Ca
8.87	KNO_3	206.5 ppm K 60.9 ppm N
16.56	$MgSO_4$	87.5 ppm Mg 113.8 ppm S
9.45	KH_2PO_4	143.5 ppm K 113.8 ppm P

Appendix Table 6. F values from analysis of variance for effects of soluble salts and biuret on height, leaf count and leaf area of Dieffenbachia amoena 'Tropic White' after 16 weeks.

Source	Height (cm)	Number of Leaves	New Leaves	Old Leaves	Leaf Area (cm^2)
Soluble salts	4.27*	3.09	6.86**	0.36	3.02
Biuret	0.92	1.37	6.33**	1.44	1.40
Salt x Biuret	0.59	0.34	2.11	0.72	1.43

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 7. F values form analysis of variance for effects of soluble salts and biuret on leaf bleaching and Xanthomonas leaf spots of Dieffenbachia amoena 'Tropic White' after 16 weeks.[z]

Source	Number of Leaf Spots	Spot Area (cm^2)	Leaves with Bleaching
Soluble Salts	2.14	1.93	1.64
Biuret	0.37	2.22	2.37
Salt x Biuret	0.44	0.52	0.46

[z]All values not significant.

Appendix Table 8. F values from analysis of variance for effects of soluble salts, biuret and light on height, fresh weight and stem caliper of Dieffenbachia amoena 'Tropic White' after 23 weeks.

Source	Height (cm)	Fresh Weight (g)	Stem Caliper (mm)
Soluble Salts	18.65**	0.65	0.33
Biuret	3.38*	0.36	3.44*
Salt x Biuret	0.28	0.66	0.68
Salt x Light	0.09	0.15	0.10
Biuret x Light	1.57	1.07	0.33
Salt x Biuret x Light	1.15	2.61*	0.84

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 9. F values from analysis of variance for effects of soluble salts, biuret and light on leaf count and leaf area of *Dieffenbachia amoena* 'Tropic White' after 23 weeks.

Source	Number of Leaves	Old Leaves	New Leaves	Leaf Area (cm^2)
Soluble Salts	18.74**	13.96**	0.28	2.03
Biuret	1.00	0.34	1.63	5.41**
Salt x Biuret	0.33	0.98	1.23	1.66
Salt x Light	1.06	0.66	1.36	2.60
Biuret x Light	0.14	0.01	0.19	0.74
Salt x Biuret x Light	1.74	3.48*	1.18	1.19

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 10. F values from analysis of variance for effects of soluble salts, biuret and light on leaf bleaching and Xanthomonas leaf spots of Dieffenbachia amoena 'Tropic White' after 23 weeks.

Source	Number of Leaf Spots	Spot Area (cm^2)	Leaves with Bleaching
Soluble Salts	2.00	1.54	45.20**
Biuret	1.23	0.83	15.16**
Salt x Biuret	0.23	0.45	4.34**
Salt x Light	0.31	2.84	10.19**
Biuret x Light	1.51	0.10	4.52*
Salt x Biuret x Light	0.48	0.59	4.62**

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 11. Results of t-tests for the effect of light levels on height, fresh weight, stem caliper, leaf counts, leaf area, leaf bleaching and Xanthomonas leaf spots of Dieffenbachia amoena 'Tropic White' after 23 weeks.

	T Value
Height (cm)	1.17
Fresh Weight (g)	0.52
Stem Caliper (mm)	2.50*
Number of Leaves	0.91
Old Leaves	2.06*
New Leaves	1.77
Leaf Area (cm^2)	1.17
Number of Leaf Spots	1.65
Spot Area (cm^2)	1.62
Leaves with Bleaching	3.15**

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 12. F values from analysis of variance for effects of of soluble salts, biuret and light on tissue composition of Dieffenbachia amoena 'Tropic White' after 23 weeks.

	Source					
	Soluble Salts (S)	Biuret (B)	S x B	S x Light	B x Light	S x B x Light
Nitrogen	5.15*	2.85	1.63	0.15	0.21	0.75
Phosphorus	24.19**	2.69	2.90*	0.03	1.60	1.40
Potassium	11.17**	2.38	1.34	0.68	1.08	0.34
Calcium	33.87**	0.11	0.78	1.91	2.33	0.67
Magnesium	163.36**	0.34	0.23	0.81	0.74	0.21
Sulfur	2.77	0.10	0.47	1.63	0.94	0.18
Sodium	483.18**	0.55	1.28	0.19	0.70	1.50
Manganese	1.04	1.27	1.21	0.10	0.21	0.70
Iron	2.74	0.57	2.20	3.59*	2.98	0.32
Copper	15.35**	1.29	1.33	1.17	1.31	0.98
Zinc	10.89**	2.00	1.53	0.65	0.47	0.26

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 13. F values from analysis of variance for effects of nitrogen sources on height, fresh weight, percent roots, leaf count, leaf area, percent leaves with virus and percent leaves with cupping of Dieffenbachia oerstedii 'Variegata'.

	Treatment	NO_3 vs NH_4 and Urea	NH_4 vs Urea
Height (cm)	5.83*	11.24*	0.42
Fresh Weight (g)	10.24**	13.67**	6.81*
Percent Roots	11.65**	15.81**	26.10**
New Leaves	9.76**	10.14*	9.39*
Old Leaves	2.51		
Number of Leaves	6.09*		
Leaf Area (cm^2)	13.90*		
Percent Virus	0.36		
Percent Cupping	52.58**		

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 14. F values from analysis of variance for effects of nitrogen source on tissue composition of Dieffenbachia oerstedii 'Variegata'.

	Nitrogen Source
Nitrogen	7.06*
Nitrate	10.28**
Phosphorus	5.56*
Potassium	24.13**
Calcium	7.23*
Magnesium	85.63**
Sulfur	28.42**
Manganese	6.45*
Iron	4.60*
Copper	2.96
Zinc	16.68**
Sodium	1.98

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 15. F values from analysis of variance for effects of calcium and soluble salts on height, fresh weight, number of roots, number of leaves and number of leaves per shoot of Dieffenbachia maculata 'Perfection Compacta'.

Source	Height (cm)	Fresh Weight (g)	Number of Roots	Number of Leaves	Leaves per Shoot
Calcium	2.80	4.56*	7.61*	1.00	4.49*
linear	3.29	2.78	3.97	1.98	0.34
quadratic	2.31	6.35*	11.26**	0.02	8.63**
Soluble Salts	7.33**	9.99**	3.10	3.32*	1.81
linear	0.82	1.26	0.19	6.07*	1.62
quadratic	13.83**	18.72**	6.03*	0.55	2.00
Calcium x Salt	0.46	2.10	0.84	2.09	0.86

*Significant at the 0.05 level.

**Significant at the 0.01 level.

Appendix Table 16. F values from analysis of variance for effects of fertilization level on height, fresh weight, number of leaves and leaf area of Dieffenbachia amoena 'Tropic White'.

	Treatment
Height	129.41**
Fresh Weight	108.14**
Number of Leaves	11.70**
Leaf Area	116.26**

**Significant at the 0.01 level.

Appendix Table 17. F values from analysis of variance for effects of fertilization level and leaf sampling position on tissue composition of Dieffenbachia amoena 'Tropic White'.

	Source	
	Fertilization Level	Leaf Sampling Position
Nitrogen	103.10**	8.00**
Phosphorus	34.20**	5.74**
Potassium	54.14**	102.26**
Calcium	42.96**	0.41
Magnesium	0.74	6.14**
Sulfur	18.76**	7.77**

**Significant at the 0.01 level.

Appendix Table 18. F values from analysis of variance for effects of fertilization level on tissue composition of Dieffenbachia amoena 'Tropic White' at 4 leaf sampling positions.

	Leaf 1	Leaf 2	Leaf 3	Leaf 4
Nitrogen	246.7**	64.0**	63.4**	15.9**
Phosphorus	7.0*	3.6	13.2*	5.6*
Potassium	13.5**	93.1**	23.4**	3.7
Calcium	10.6*	15.1**	3.3	18.5**
Magnesium	0.0	10.5*	0.4	70.3**
Sulfur	13.0**	5.3*	0.2	20.7**

*Significant at the 0.05 level.

**Significant at the 0.01 level.

LITERATURE CITED

1. Aragaki, M. and J.Y. Uchida. 1981. Dieffenbachia cane rot complex. H.I.T.A.H.R. Brief No. 010.

2. Bangerth, F. 1979. Calcium-related physiological disorders of plants. Ann. Rev. Phytopathol. 17:97-122.

3. Beaufils, E.R. 1973. Diagnosis and recommendation integrated system (DRIS). Soil Science Bull. No.1. Dept. of Soil Science and Agrometeorology. University of Natal. Pietermaritzburg. 132pp.

4. Bennett, W.F., J. Pesek and J.J. Hanway. 1964. Effect of nitrate and ammonium on growth of corn in nutrient solution sand culture. Agron. J. 56:342-345.

5. Bernstein, L. and L.E. Francois. 1975. Effects of frequency of sprinkling with saline waters compared with daily drip irrigation. Agron. J. 67:185-190.

6. Bernstein, L., L.E. Francois and R.A. Clark. 1972. Salt tolerance of ornamental shrubs and ground covers. J. Amer. Soc. Hort. Sci. 97:550-556.

7. Burris, R.H. 1959. Nitrogen nutrition. Ann. Rev. Plant. Physiol. 10:301-328.

8. Chadha, K.L., J.S. Samara and R.S. Thakur. 1980. Standardization of leaf-sampling technique for mineral composition of leaves of mango cultivar 'Chausa'. Scientia Horticulturae. 13:323-329.

9. Chase, A.R. 1980. Dasheen mosaic virus of dieffenbachia. Foliage Digest. 3(7):7-8.

10. Chase, A.R. 1981a. Common fungal leafspot diseases of foliage plants. Foliage Digest. 4(5):7-11.

11. Chase, A.R. 1981b. Common fungal stem rot diseases of foliage plants. Foliage Digest. 4(6):3-4.

12. Chase, A.R. 1981c. Common viral diseases of foliage plants. Foliage Digest. 4(9):9-11.

13. Clark, R.B. and A. Wallace. 1961. C^{14}-Biuret accumulation and translocation by bush beans. Proc. Amer. Soc. Hort. Sci. 77:393-400.

14. Colgrove, M.S. Jr. and A.N. Roberts. 1956. Growth of Azalea as influenced by ammonium and nitrate nitrogen. Proc. Amer. Soc. Hort. Sci. 68:522-536.

15. Conover, C.A. and J.E. NeSmith. 1966. Soluble salt levels and determinations as related to quality foliage plant production. Florida Foliage Grower. 3:1-6.

16. Conover, C.A. and R.T. Poole. 1975. Influence of shade and fertilization on growth of container grown Araucaria, Dieffenbachia, Dizygotheca and Dracaena. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 19:247-252.

17. Conover, C.A. and R.T. Poole. 1977a. Influence of irrigation method and fertilizer source and level on growth of four foliage plants. Proc. Fla. State Hort. Soc. 90:312-313.

18. Conover, C.A. and R.T. Poole. 1977b. Influence of potting media and fertilizer source and level on growth of four foliage plants on capillary mats. Proc. Fla. State Hort. Soc. 90:316-318.

19. Conover, C.A. and R.T. Poole. 1981. Influence of light and fertilizer levels and fertilizer sources on foliage plants maintained under interior environments for one year. J. Amer. Soc. Hort. Sci. 106:571-574.

20. Cox, E.F. and A.S. Dearman. 1981. The effect of trickle irrigation, misting and row position on the incidence of tipburn of field lettuce. Scientia Horticulturae. 15:101-106.

21. Criley, R.A. and W.H. Carlson. 1970. Tissue analysis standards for various floricultural crops. Florists' Review. 146:19-20.70-73.

22. Dickey, R.D. and J.N. Joiner. 1966. Identifying elemental deficiencies in foliage plants. Florida Foliage Grower. 3(5):1-2.

23. Epstein, E. 1972. Mineral nutrition of plants: principles and practices. John Wiley and Sons. New York.

24. Franceschi, V.R. and H.T Horner Jr. 1980. Calcium oxalate crystals in plants. Botanical Review. 46:361-427.

25. Francois, L.E. and R.A. Clark. 1978. Salt tolerance of ornamental shrubs, trees and Iceplant. J. Amer. Soc. Hort. Sci. 103:280-283.

26. Frear, C.B. 1980. Growth of Dracaena deremensis 'Warneckii Compacta' as influenced by pH, specific ions and soluble salts. Thesis. Dept. of Hort. University of Hawaii.

27. Gauch, H.G. 1972. Inorganic plant nutrition. Dowden, Hutchinson and Ross, Inc. Stroudsburg. Pa.

28. Henley, R.W. 1977. Foliar analysis of tropical foliage plants. Florida Foliage Grower. 14(8):1-3.

29. Henley, R.W. and R.T. Poole. 1981. A study of water and fertilizer requirements of selected foliage plants. Foliage Digest. 4:12-13.

30. Hewitt, E.J. 1966. Sand and water culture methods used in the study of plant nutrition. Commonwealth Agricultural Bureaux. Eastern Press, Ltd. London.

31. Higaki, T., H.P. Rasmussen and W.J. Carpenter. 1980a. Calcium deficiency of Anthurium andreanum Lind. J. Amer. Soc. Hort. Sci. 105:438-440.

32. Higaki, T., H.P. Rasmussen and W.J. Carpenter. 1980b. Color breakdown in Anthurium(Anthurium andreanum Lind.) spathes caused by calcium deficiency. J. Amer. Soc. Hort. Sci. 105:441-444.

33. Holland, D.A. 1966. The interpretation of leaf analyses. J. Hort. Sci. 41:311-329.

34. Hughes, H.E. and J.J. Hanan. 1978. Effect of salinity in water supplies on greenhouse rose production. J. Amer. Soc. Hort. Sci. 103:694-699.

35. Impey, R.L. and W.W. Jones. 1960. Effects of biuret on nitrogen status of Washington Navel and Valencia orange leaves. Proc. Amer. Soc. Hort. Sci. 76:186-192.

36. Joiner, J.N., C.A. Conover and R.T. Poole. 1981. Nutrition and fertilization. IN: Foliage plant production. J.N. Joiner, ed. Prentice-Hall, Inc. Englewood Cliffs. N.J. pp229-268.

37. Kirkby, E.A. and K. Mengel. 1967. Ionic balance in different tissues of the tomato plant in relation to nitrate, urea, or ammonium nutrition. Plant. Physiol. 42:6-14.

38. Klougart, A. 1976. Urea as a nitrogen source for pot plants. Acta Horticulturae. 64:103-114.

39. Kohl, H.C. Jr., O.R. Lunt and A.M. Kofranek. 1959. Response of Lilium longiflorum var. Croft to high salt and boron concentrations. Proc. Amer. Soc. Hort. Sci. 76:644-648.

40. Koo, R.C.J. and T.W. Young. 1972. Effects of age and position on mineral composition of mango leaves. J. Amer. Soc. Hort. Sci. 97:792-794.

41. Koo, R.C.J. and T.W. Young. 1977. Effects of age, position, and fruiting status on mineral composition of 'Tonnage' avocado leaves. J. Amer. Soc. Hort. Sci. 102:311-313.

42. Kuo, C.G., J.S. Tsay, C.L. Tsay and R.J. Chen. 1981. Tipburn of chinese cabbage in relation to calcium nutrition and distribution. Scientia Horticulturae. 14:131-138.

43. Lange, A.H., W.L. Ehrler, and K.C. Hamner. 1958. Effect of environment on the uptake-transport of calcium and phosphorus by bean plants. Proc. Amer. Soc. Hort. Sci. 45:425-430.

44. Marlatt, R.B. 1978. Brown leaf spot of dieffenbachia. Foliage Digest. 1(5):10.

45. Mason, G.F. and C.G. Guttridge. 1975. The influence of relative humidity and nutrition on leaf tipburn of strawberry. Scientia Horticulturae. 3:339-349.

46. Maynard, D.N. 1979 Nutritional disorders of vegetable crops: a review. J. Plant Nutrition. 1:1-23.

47. Maynard, D.N., and A.V. Barker. 1969. Studies on the tolerance of plants to ammonium nutrition. J. Amer. Soc. Hort. Sci. 94:235-239.

48. McCulloch, L. and P.P. Pirone. 1939. Bacterial leaf spot of Dieffenbachia. Phytopathology. 29:956-962.

49. McFadden, L.A. 1961. Bacterial stem and leaf rot of Dieffenbachia in Florida. Phytopathology. 51:663-668.

50. Monk, R.W. and H.H. Wiebe. 1961. Salt tolerance and protoplasmic salt hardiness of various woody and herbaceous ornamental plants. Plant Physiol. 36:478-482.

51. Munnecke, D.E. 1960. Bacterial stem rot of Dieffenbachia. Phytopathology. 50:696-700.

52. Nelson, P.V. and J.W. Boodley. 1963. Selection of a sampling area for tissue analysis of carnation. Proc. Amer. Soc. Hort. Sci. 83:745-752.

53. Nelson, P.V. and J.W. Boodley. 1964. Development of a set of standard leaf composition values for carnation. Proc. Amer. Soc. Hort. Sci. 86:641-649.

54. Pill, W.G. and V.N. Lambeth. 1977. Effects of NH4 and NO3 nutrition with and without pH adjustment on tomato growth, ion composition, and water relations. J. Amer. Soc. Hort. Sci. 102:78-81.

55. Poole, R.T. and C.A. Conover. 1981. Influence of N-P-K factorial fertilization on growth characterisitics and foliar content of 4 foliage plants. HortScience. 16:771-772.

56. Poole, R.T., C.A. Conover and J.N. Joiner. 1976. Chemical composition of good quality tropical foliage plants. Proc. Fla. State Hort. Soc. 89:307-308.

57. Rains, D.W. 1972. Salt transport by plants in relation to salinity. Ann. Rev. Plant. Physiol. 23:367-388.

58. Reinbothe, H. and K. Mothes. 1961. Urea, ureides and guanidines in plants. Ann. Rev. Plant. Physiol. 12:129-150.

59. Rodrigues, S.J. 1967. Variation in chemical composition of guava leaves(Psidium guajava L.) as affected by position in the terminals. J. Ag. Un. of Puerto Rico. 51:252-259.

60. Scaife, M.A. and D.T. Clarkson. 1978. Calcium-related disorders in plants-a possible explanation for the effect of weather. Plant and Soil. 50:723-725.

61. Smith, P.F. 1962. Mineral analysis of plant tissues. Ann. Rev. Plant. Physiol. 13:81-108.

62. Summer, M.E. 1974. An evaluation of Beaufils' physiological diagnostic techinque for determining the nutrient requirement of crops. Proc. 7th Intern. Colloquium on Plant Analyisi and Fertilizer Problems. pp437-446.

63. Thakur, R.S., G.S. Prasada Rao, K.L. Chadha and J.S. Samara. 1981. Variation in mineral composition of mango leaves as contributed by leaf sampling factors. Commun. in Soil Sci. Plant Anal. 12:331-343.

64. Townsend, A.M. 1980. Response of selected tree species to sodium chloride. J. Amer. Soc. Hort. Sci. 105:878-883.

65. Vines, H.M. and R.T. Wedding. 1960. Some effects of ammonia on plant metabolism and a possible mechanism for ammonia toxicity. Plant. Physiol. 35:820-825.

66. Wallace, A. and R.T. Mueller. 1980. Calcium uptake and distribution in plants. J. Plant Nutrition. 2:247-256.

67. Waters, W.E. and W. Llewellyn. 1968. Effects of coated-slow-release fertilizer on growth responses, chemical composition and soil salinity levels for foliage plants. Proc. Fla. State Hort. Soc. 81:380-388.

68. Webster, G.C., R.A. Berner and A.N. Gansa. 1957. The effect of biuret on protein synthesis in plants. Plant. Physiol. 32:60-61.

69. Yamauchi, S. 1982. Personal Communication.

70. Young, T.W. and R.C.J. Koo. 1971. Variations in mineral content of Florida mango leaves. Proc. Fla. State Hort. Soc. 84:298-302.

71. Young, T.W. and R.C.J. Koo. 1977. Influence of soil and cultivar on mineral composition of avocado leaves in Florida. J. Amer. Soc. Hort. Sci. 102:308-311.

72. Zettler, F.W. and B.B. Rhodes. 1975. Calcium oxalate variability in Dieffenbachia seedlings. HortScience. 10:481-482.

73. Zindler-Frank, E. 1975. On the formation of the pattern of crystal idioblasts in Canavalia ensiformis D.C. VII. Calcium and oxalate content of the leaves in dependence of calcium nutrition. Z. Pflanzenphysiol. Bd. 77:80-85.